Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through sampling of the subsistence fishery (1995-2007)

L.A. Harwood, S. Sandstrom, and E. Linn

Central and Arctic Region
Fisheries and Oceans Canada
Yellowknife, NT X1A 1E2

2009

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2891

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, e'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complèrwa. Le titre exact paraît au-dessus du résumés de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*,et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministére.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et aprés le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur don't le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2891

2009

STATUS OF ANADROMOUS DOLLY VARDEN (*Salvelinus malma*) OF THE RAT RIVER, NORTHWEST TERRITORIES AS ASSESSED THROUGH SAMPLING OF THE SUBSISTENCE FISHERY (1995-2007)

by

L. A. Harwood, S. Sandstrom, and E. Linn

Central and Arctic Region
Fisheries and Oceans Canada
Yellowknife, NT X1A 1E2

©Her Majesty the Queen in Right of Canada 2009.

Cat. No. Fs 97-4/2891E ISSN 0706-6473

Correct citation for this publication is:

Harwood, L.A., Sandstrom, S., and Linn, E. 2009. Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through sampling of the subsistence fishery (1995-2007). Can. Manuscr. Rep. Fish. Aquat. Sci. 2891: vii + 53 p.

TABLE OF CONTENTS

LIST OF FIGURES....iii
LIST OF TABLES....v
ABSTRACT....vi
RÉSUMÉ....vii
INTRODUCTION....1
STUDY AREA....1
THE FISHERY....2
METHODS....3
Sampling the Fishery....3
DATA ANALYSIS....4
RESULTS and DISCUSSION....5
Size and Timing of the Fishery....5
Catch-Per-Unit-Effort (CPUE) and Mesh Size....6
Tag Returns....7
Biological Indicators....7
Fork Length....7
Age and Mortality....8
Life History Composition, Sex Ratio and Maturity....9
Somatic Condition....9
Growth....9
SUMMARY....11
ACKNOWLEDGEMENTS....14
LITERATURE CITED....14

LIST OF FIGURES

Figure 1. The Yukon North Slope showing the location of Dolly Varden rivers (known spawning locations denoted with black circle)....17

Figure 2. Rat River and Big Fish River Dolly Varden fishing and monitoring sites....18

Figure 3. Timing (range and mode) of the Rat River Dolly Varden subsistence fishery, 1995-2007....19

Figure 4. Estimated harvest of Rat River Dolly Varden from the subsistence fishery, 1995-2007....20

Figure 5. Mean effort-weighted mesh size vs year, Rat River Dolly Varden subsistence fishery....21

Figure 6. Mean CPUE at four monitoring sites, Rat River, 1996-2007....22

Figure 7. Mean fork length of male and female spawning Dolly Varden caught at the Rat River subsistence fishery, 1995-2007 23

Figure 8. Mean fork length of silver (current-year spawning) Dolly Varden caught at the Rat River subsistence fishery, 1995-2007 24

Figure 9. Size distribution of silver (current-year non-spawning) Dolly Varden caught in the subsistence fisheries at the community monitoring sites, 1995-2007 25

Figure 10. Mean age of male and female spawning Dolly Varden and silver Dolly Varden caught at the Rat River subsistence fishery, 1995-2007 27

Figure 11. Age-frequency distribution of SILVER Dolly Varden caught in the subsistence fisheries at the monitoring sites, 1995-2007 28

Figure 12. Age-frequency distribution of FEMALE SP Dolly Varden caught in the subsistence fisheries at the monitoring sites, 1995-2007 30

Figure 13. Age-frequency distribution of MALE SP Dolly Varden caught in the subsistence fisheries at the monitoring sites, 1995-2000 32

Figure 14. Mean length at age for Dolly Varden caught in the subsistence fishery at five year intervals (+2007) 34

Figure 15. Mean fork length of 6-y old current-year female spawners 1989-2001 35

Figure 16. Mean fork length for 6-yr old female silvers, 1989-2005 36

Figure 17. Mean length of 6-yr old male Dolly Varden, 1989-2005 37

Figure 18. Mean fork length of current-year spawning female Dolly Varden caught in the subsistence fishery, 1989-2005 38

Figure 19. Comparison of the size frequency distribution of current-year spawning females caught in the subsistence harvest vs the fall assessments at Fish Hole .. 39

Figure 20. Mean length-at-age for female spawners aged 5, 6 and 7 years from 1989-2001 40

Figure 21. Comparison of growth rates of recaptured repeat female spawners in 1996 vs 2005 41

Figure 22. Comparison of length-weight relationship of female spawners between 1992 and 2002 42

Figure 23. Trends in the number of ice-free days and mean length of spawning females, 1995-2007 42

Figure 24. Residuals of mean annual somatic condition factor (K) vs date of ice clearing for the period 1996-2007 (Ice data courtesy of Humfrey Melling, IOS, 2008) 43

LIST OF TABLES

Table 1. Mesh size information for the 1995-2007 Rat River Dolly Varden subsistence fishery 44

Table 2. Dates for the Rat River Dolly Varden subsistence fishery, 1995-2007 45

Table 3. Rate of tag return at the different monitoring sites, Rat River Dolly Varden recaptures 46

Table 4. Size, condition and life history summary for the sampled catch, Rat River subsistence fishery, 1995-2007 47

Table 5. Mean length-at-age for Dolly Varden from the Rat River (1983) and from the subsistence fishery, 1986-2007 48

Table 6. Rat River Dolly Varden instantaneous mortality rate (Z), annual survival rate (S) and annual mortality rate (A) 49

Table 7. Mean length-at-age for Dolly Varden from the Rat River (1983) and from the subsistence fishery, 1986-2007 50

Table 8. Comparison of the size of female spawners among sites, using years/ locations with a minimum of 20 fish 51

Table 9. Proportion of repeat spawners among tag recaptured Dolly Varden from the 1995 and 2004 tagging programs (see also Sandstrom and Harwood 2008) 52

Table 10. Fecundity estimates for various size classes of spawning females, 1989-1992 and 2002-2005 53

ABSTRACT

Harwood, L.A., Sandstrom, S., and Linn, E. 2009. Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through sampling of the subsistence fishery (1995-2007). Can. Manuscr. Rep. Fish. Aquat. Sci. 2891: vii + 53 p.

One or more stocks of anadromous Dolly Varden, known locally as "char", inhabit the Rat River and its tributaries. Rat River Dolly Varden represent one of six known stocks of the northern form of Dolly Varden in Canada. The Dolly Varden that inhabit this system show a fair degree of genetic diversity, compared with stocks in neighbouring systems. Fishermen from two adjacent land claim groups, the Gwich'in and the Inuvialuit, harvest Dolly Varden from the Rat River stock(s). The fishery has been monitored through the present harvest-based sampling program 1995-2007. Over 98% of the fish caught and monitored in this study were caught using 102 mm (4") or 114 mm (4.5") mesh nets. There were no significant differences in mean fork length due to mesh size for spawning females or spawning males. Declines in CPUE were apparent at all monitoring sites starting in 2000-2002, after which time the CPUE remained at a low level at all sites through to 2007. The following aspects of the fishery have remained unchanged over the monitoring time series: silvers (current-year non-spawners) are caught more often than spawners (approximately 3 to 1), females outnumber males (approximately 2 to 1), and anadromous males remain at a low level in the stock. The modal age has remained at 5 or 6 years throughout the study, and the age-frequency distributions showed no clear shift in either direction of the age structure of the catch over time. There has been weak representation of the older age classes throughout all years of the study, but an apparent increase in the proportion of 4 y olds (smolts) in recent years. Significant increases in the size-at-age over the time series, relatively stable sex and maturity composition, and the recent observed pulse of juvenile production at the Fish Hole are all encouraging signs for this stock. This increase in growth rate, and an increase in somatic condition in certain years, appears related to the timing of break up of the annual sea ice in the SE Beaufort Sea. Timing of break up in turn influences the timing of the zooplankton bloom and thus the Dolly Varden's access to quantity and quality of prey.

Key words: Dolly Varden, char, monitoring, stock status, trend, age, length, condition, mortality, sex ratio, CPUE

RÉSUMÉ

Harwood, L.A., Sandstrom, S., and Linn, E. 2009. Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through sampling of the subsistence fishery (1995-2007). Can. Manuscr. Rep. Fish. Aquat. Sci. 2891: vii + 53 p.

Un ou plusieurs stocks de Dolly Varden anadrome, appelée localement « char » en anglais, sont présents dans la rivière Rat et ses affluents. La Dolly Varden de la rivière Rat constitue l'un des six stocks connus de la forme nordique de cette espèce au Canada. La Dolly Varden qui vit dans ce système fluvial présente un niveau de diversité génétique plus élevé que les stocks des réseaux voisins. Elle est exploitée par les pêcheurs de deux groupes voisins ayant fait une revendication territoriale, les Gwich'ins et les Inuvialuit. La pêche est surveillée à l'aide du programme actuel d'échantillonnage des captures (1995-2007). Plus de 98 % des poissons observés durant cette étude ont été capturés à l'aide de filets à mailles de 102 mm (4 po) ou de 114 mm (4,5 po). Il n'y avait aucune différence notable dans la longueur à la fourche moyenne attribuable à la taille des mailles chez les femelles prêtent à frayer et les mâles reproducteurs. Une baisse évidente des PUE a été observée sur tous les sites de surveillance à partir de 2000-2002, période après laquelle les PUE sont demeurées faibles dans tous les sites jusqu'en 2007. Les aspects suivants de la pêche sont demeurés les mêmes durant la série chronologique de surveillance : les saumons cohos (non-géniteurs de l'année courante) sont capturés plus fréquemment que les géniteurs (ratio d'environ 3 pour 1), le nombre de femelles est supérieur à celui des mâles (ratio d'environ 2 pour 1), et les mâles anadromes sont peu nombreux dans le stock. L'âge modal est demeuré à 5 ou 6 ans tout au long de l'étude et les distributions de fréquences des âges n'ont montré aucun changement notable de la structure par âge des captures avec le temps. Au cours de ces années d'étude, les classes plus âgées ont été peu représentées, mais la proportion des individus âgés de 4 ans (smolts) s'est manifestement accrue depuis les dernières années. Les augmentations marquées de la taille selon l'âge au cours des séries chronologiques, la répartition entre les sexes et la composition à la maturité plutôt stables, et le récent regain de production des juvéniles à la fosse à poissons sont tous des signes positifs pour cette population. L'augmentation du taux de croissance et de la condition somatique durant certaines années semble liée à la période de débâcle de la glace annuelle dans la partie sud-est de la mer de Beaufort. De fait, cette période influe sur la prolifération du zooplancton et permet ainsi à la Dolly Varden d'avoir accès à un grand nombre de proies de qualité.

Mots clés: Omble Dolly Varden, surveillance des pêches, état de la population, tendance, âge, taille, condition corporelle, mortalité, rapport entre les sexes, PUE (Prises par Unité d'Effort)

INTRODUCTION

Dolly Varden *(Salvelinus malma)*, described by Reist (1989), inhabit the Rat River watershed. Spawning and over-wintering areas for Dolly Varden are located at spring-fed reaches of Fish Creek, a tributary of the upper Rat River. In the Western Canadian Arctic, Dolly Varden occur to the west of the Mackenzie River (e.g., in the Vittrekwa River of the upper Peel River drainage, the Big Fish River, the Babbage River, the Firth River, Joe Creek and the Rat River , Fig. 1). Arctic char (*Salvelinus alpinus*) occur primarily to the east of the Mackenzie drainage (e.g., Hornaday River, Kuujjua River).

The Rat River is 130 km in length, originating in the Richardson Mountains and flowing into the Husky Channel of the Mackenzie River SE of Inuvik, NWT (Fig. 1). The anadromous char leave the Rat River in the spring, migrating toward the Beaufort Sea through the western portions of the Mackenzie River delta. During summer, they feed in near shore marine areas, returning upstream in August to over wintering and spawning habitats. Field observations (Sandstrom, Harwood, Mitchell, pers. comm.) and genetic results (Reist 1989) suggest that the Dolly Varden that spawn and over-winter in the Rat River may comprise two or more different stocks.

Concerns from residents of Fort McPherson about the status and health of the Rat River Dolly Varden prompted DFO to conduct studies on the Rat River in 1983, 1986 and 1989 (Gillman and Sparling 1985; Sparling and Stewart 1986; Stephenson and Lemieux 1990). The subsistence harvest at one site was monitored annually since 1989 (Harwood et al. 1994; Harwood 2001). The objective of this study was to assess the status of the stock through sampling of the subsistence catches from 1995-2007, building on earlier years of monitoring. A separate study at Fish Creek on the Rat River reports on assessments at the spawning site for the same period as the monitoring study reported here (Sandstrom et al. 2009).

Annual changes in the biological parameters and the success of the fishery, monitored over an extended period of time, provide a means by which to assess the status of the stock and the sustainability of the fishery. This monitoring program is only one of several Dolly Varden management initiatives underway by the harvesters of Fort McPherson and Aklavik, working with the Gwich'in Renewable Resources Board (GRRB www.grrb.ca), the Fisheries Joint Management Committee (FJMC www.fjmc.ca) and Fisheries and Oceans Canada.

STUDY AREA

The Rat River straddles the Yukon-Northwest Territories border, and flows from headwaters in the Richardson Mountains along a 130 km (80 miles) course, entering the Husky Channel of the Mackenzie River 35 km (22 miles) north-west of Fort McPherson, NT (Fig. 1). Trees are confined to the valleys and lower slopes and the rest of the basin area is covered by tundra vegetation. The bedrock is mainly sandstone, with some limestone in the northern sections. One tributary, Fish Creek,

has many deep pools and is fed by one or more year-round springs. Water temperatures at the spring source area are in the 4-5 C° range.

The high gradient rivers in this area cease flowing in the winter and freeze completely over much of their length. The exception to this is areas where groundwater springs enter. These perennial springs produce a system of "fish holes", areas that remain open year-round, and thus provide critical over-wintering and spawning habitat for the Dolly Varden. Downstream of the "fish holes", groundwater flows throughout the winter and this produces an aufeis (ice) field, also known as the "braided" area during ice-free periods. Spawning and over-wintering sites are relatively well known and recent studies have documented that the physical characteristics of the "fish holes" at a neighboring North Slope river change over time, as sodium, water and silt levels fluctuate (Clark et al. 2001).

THE FISHERY

During the summer months, Rat River Dolly Varden are taken along the Beaufort Sea coast, mainly at whaling and fishing camps established along the Yukon coast and at Shingle Point in the Northwest Territories. This is a mixed-stock fishery, with Dolly Varden from the Babbage, Firth, Big Fish and Rat, and presumably Vittrekwa river systems being caught there as well (Fig. 1). Dolly Varden from Alaskan stocks are likely also taken in this fishery.

Once the Rat River Dolly Varden begin their return migration to over-wintering and spawning areas, they encounter fishermen's nets at a number of locations along the way, usually between late August and mid-September (Fig. 2). These are the main times and places that Rat River Dolly Varden are harvested, with most of the fishing taking place for approximately 3-4 weeks each year. Floating, monofilament gillnets with meshes 102 mm (4") and 114 mm (4 ½") are the most common sizes used, usually 25 m in length and 30 meshes deep. Smaller and larger mesh nets (e.g., 89 mm or 3½", 127 mm or 5", and 140 mm or 5.5") were used only occasionally by fish harvesters involved in the present study.

Fishing sites (Fig. 2) include the Aklavik town site, the mouth of Husky Channel, Big Eddy along the Husky Channel, the confluence of Husky Channel and the mouth of the Rat River, and finally, Destruction City on the Rat River itself. There is no fishing for Dolly Varden at the fish holes of Fish Creek on the Rat River at the present time, and has not taken place since the mid-1980's (J. Francis, pers. comm.). A voluntary closure, by the communities of Aklavik and Fort McPherson, for fishing at the fish holes of Fish Creek has been in place since 2006.

METHODS

SAMPLING THE FISHERY

This study, initiated in 1995, involved fish monitors at each of five locations along the return migration route of the Rat River Dolly Varden. Cost constraints necessitated a reduction to four monitoring sites in 1999, and finally three sites in 2004. The fish harvesters who were hired, termed "monitors", were selected by the Aklavik and Fort McPherson Renewable Resource Councils (RRC's), and started their work once the Dolly Varden began their upstream migration past their monitoring site.

Each monitor was hired for 31 consecutive days in each year, although this was extended in some years if Dolly Varden were still running when the monitoring period was over. The head monitor, John Carmichael, was stationed at Big Eddy and set 1-2 nets in late July or early August of each year to determine the start of the run. His observations and advice were used to determine when the run had started and thus when the monitoring program would start.

The monitors kept records of their own and nearest neighbors' catches, to ensure that catches from all fishermen were represented in the study. The same monitors have been involved in the data collection at each site throughout the 13 y of the study, with the exception of the mouth of the Rat River site where three different monitors worked (the late Joe Vittrekwa, 1995-1997; Lazarus Francis 1998-1999; and Billy Wilson 2000-2007). DFO biologists provided sampling materials and instructions prior to the start of each field season, and site visits during the course of the fishery and monitoring study. Biological data from Dolly Varden collected prior to 1995 are reported in Harwood et al. (2001).

Monitors were tasked with keeping records of the total number of Dolly Varden caught, as well as the number, length and mesh size of the gillnets used, and the location and duration of each set. They also dead sampled 100 Dolly Varden per season in 1995-2005. In 2006 and 2007, sample size was reduced to 40 per season per site, in keeping with harvest restrictions established on the fishery for those years. This restriction resulted in smaller sample sizes for those years. A voluntary closure for fishing at the Fish Holes has been implemented by the community of Fort McPherson since 2006.

Dead sampling involved reporting mesh size used to catch the fish (started in 2001), and for each dead sampled fish, measuring fork length, round weight, determining sex and maturity. Any Dolly Varden harvested that had floy or radio tags were included in the dead sample. The monitors were instructed to select the fish for dead sampling randomly from the day's catch, and to spread the sampling effort throughout the duration of the fishery. In 2000, 2001 and 2007, the monitors also took 50-100 fin and tissue samples for future genetic analyses. Monitors also recorded qualitative information about weather, water levels, and debris twice per day during each day of monitoring, in all years of the study.

Sagittal otoliths were removed from all dead sampled Dolly Varden, and were placed in a scale envelope for age determination. All age determinations were conducted by G. Carder, according to Nordeng (1961).

DATA ANALYSIS

To estimate the size of the annual harvest, the relevant data sets were compiled from the monitors, the Gwich'in Harvest Study, the Inuvialuit Harvest Study and the 1999 DFO Harvest Study (Stephenson, S., DFO Area Office). The total annual removal was estimated by summing:

- 50% of the estimated Inuvialuit catch at Shingle Point (assumes the other 50% of the catch originated from other North Slope rivers such as the Big Fish River and Babbage River);
- The total of all Dolly Varden caught in the Peel Channel at Aklavik, by both Inuvialuit and Gwich'in fishermen; and,
- The total of all Dolly Varden caught at Husky Channel, Big Eddy, mouth of the Rat River and Destruction City (Fig. 2).

The various data sets were scrutinized to ensure all catches were included and to ensure no duplication of records through reporting to more than one harvest study. Harvesters reporting catches were anonymous, although the coordinators of the Inuvialuit and Gwich'in Harvest Studies had access to these names and scrutinized the data to ensure records from each reporting fisher were included only once.

Catch per unit effort (CPUE) was calculated as the number of Dolly Varden/100 m/24 h, individually for each of the four "traditional fishing camp" monitoring sites and only for the monitors catches (not for the Aklavik Town site) and overall. The number of sets using each of the five different mesh sizes was tallied for 1995-2007 (Table 1). PROC GLM (General Linear Models) in SAS (1996) was used to examine for statistical differences in the mean annual CPUE for Dolly Varden harvested with five different mesh sizes used in this fishery, and a Duncan's Multiple Range test to indicate specific differences among meshes and years.

PROC GLM was also used to examine differences in the mean fork length of Dolly Varden caught using the different mesh sizes, and a Duncan's Multiple Range test to elucidate where specific differences in mesh size occurred for each of the three sex/maturity groupings – current-year spawning females, current-year spawning males, and current-year non-spawners ('silvers'). Mean fork length and mean age were calculated and tabulated for the sex/maturity groupings for 1995-2007. Mean fork length and age were also calculated for silvers, for 2001-2007, by mesh size.

PROC GLM and a Duncan's Multiple Range test were used to examine for differences in the mean length and mean age of Dolly Varden harvested among years. Age (by

sex/maturity grouping) and length-frequency (for silvers) distributions of the upstream migrants were constructed for Dolly Varden caught in the fishery (1995-2007). The percent of the samples in each of the three sex/maturity groupings, annual and overall sex ratio, and the percentage of Dolly Varden in the sample >550 mm were calculated.

A catch curve was constructed by plotting the running average of three age frequencies against log age. Instantaneous mortality rate (Z) was then calculated using a least squares regression on the descending limb of the catch curve. Only age groups that were fully recruited into the catch were used (7, 8 or 9 through 11, 12 or 13 y) following Ricker (1975). Annual survival rate (S) and annual mortality rates (A) were also calculated.

Relative condition factor (K), a measure of the relative robustness of the fish, was determined by the following formula (Anderson and Gutreuter 1983):

$$K = \frac{W \times 10^5}{L^3}$$

where, W = round weight in g and L = fork length in mm.

Mean fork length-at-age was calculated for Dolly Varden dead sampled in 1995-2007 and plotted to depict annual growth. Plots were prepared for each year class, over time, separately for current-year spawning females, current-year spawning males, and current-year non-spawners (silvers). Mean annual somatic condition was evaluated against date of clearing of the sea ice in the south east Beaufort Sea, using standardized data obtained from the Canadian Ice Service, Ottawa, Ontario. Independence of these parameters was tested by examining the residual plot.

RESULTS AND DISCUSSION

SIZE AND TIMING OF THE FISHERY

The duration of the fishery averaged 40 d (SD 5.1 d) at the five monitoring sites, and ranged from 31 to 50 days (Table 2). Patterns were similar among the five monitoring sites, within a given year. For all years pooled, the median date for the monitoring efforts (taken as proxy of the peak of the run), was Aug 18 for Husky Channel, August 21 for Big Eddy, August 26 for mouth of the Rat, and August 30 for Destruction City. This 3-5 d time lag between sites reflects the time it takes the fish to move upstream from site to site.

While there is annual variation in the timing of the start of the run (Fig. 3), the length of the fishery has remained relatively consistent among years. For this monitoring series, the year with the earliest run was 1998 (started July 28), while the latest run was 2006 (started Aug. 11).

The average annual harvest of Dolly Varden was estimated at 2383 fish for the period 1995-2001, and 726 fish annually from 2002-2007 (Fig. 4). The most recent harvests (2006-2007) consist only of 40 fish sampled by each of three monitors (e.g., approximately 120 total annually, as per restrictions presently in place for this fishery). The number of fishers active in this fishery during the monitoring period ranged from a high of 23 (1997) to a low of 3 (2007) (Table 2).

CATCH-PER-UNIT-EFFORT (CPUE) AND MESH SIZE

Catch-per-unit-effort (CPUE) can indicate changes in stock size, but at the same time, is greatly affected by changes in recruitment levels, timing of migrations, local environmental conditions and/or changes in fishing methods.

The plot of mean fishing effort weighted by mesh size showed no significant differences over time (R^2=0.1292) (Fig. 5). There were also no significant differences in the mean CPUE using mesh sizes of 102 mm (4"), 114 mm (4.5"), 127 mm (5.0") or 140 mm (5.5") ($F=20.24$, df 4,3388; $p>F<0.0001$; $p>0.05$) (Table 1). Mean CPUE for 14 sets using a 89 mm (3.5") mesh net in 1996 and 1997 was significantly greater (50.9, n=14 sets) than mean CPUE for sets that used mesh sizes of 127 and 140 mm. However, the number of sets which used 89 mm was too small and only occurred in 2 years of the series, so these data are not considered further in the CPUE analyses.

Between 1995 and 2007, and pooling catches from 102 mm (4"), 114 mm (4.5"), 127 mm (5.0") or 140 mm (5.5") meshes, the overall CPUE for the subsistence fishery averaged 27.3 Dolly Varden/100 m/24 h (range: 0-360 Dolly Varden/100 m/24 h; n=3400 sets). Mean CPUE for 1998 (74.0 Dolly Varden/100 m/24 h) was the highest value in the series, three times higher than the overall mean for 1995-2007. The 2006 CPUE value (5.4 Dolly Varden/100 m/24 h) was the lowest in the series, at 20% of the mean.

In the subsistence fishery from 1995-2007, CPUE followed the same pattern at each of the four monitoring sites (Fig. 6). Declines in CPUE were apparent at all sites starting in 2001-2003, after which time the CPUE remained at a low level at all sites through to the most recent sampling in 2007. Since the CPUE data were primarily collected by the same monitors fishing with the same gear, always in the same location, and in the same season for 13 consecutive years, they are expected to elucidate trends in the fishery, and strength of the run and size of the stock, over this time period. In 2006 and 2007, the monitors report to have continued to fish in their usual way and kept CPUE records throughout the fishery. The proportion of the catch that exceeded the 40 fish that they were allowed to keep was reported to have been released alive.

Although CPUE data were collected according to mesh size for the period 1995-2007, the dead-sampled fish were not assigned mesh sizes with which they were caught until 2001. Thus, the analysis of mesh size effects on fish size could only be done for the 2001-2007

time period. The mean length of Dolly Varden caught between 2001 and 2007 with 102 mm nets was 456.5 mm (n=1202), with 114 mm nets it was 493.8 mm (n=772). These two mesh sizes made up 98% of the fishing effort covered by the monitoring study reported here.

For the years 2001-2007, differences in mean length of harvested Dolly Varden were significant for silvers ($F=62.91$, $df=2, 1476$; $p>F<0.0001$; Duncan's Multiple Range test, $p<0.05$, $df=1476$) for the different mesh sizes, but not for current-year spawning females (Duncan's Multiple Range test, $p>0.05$, $df=389$) or for current-year spawning males (Duncan's Multiple Range test, $p>0.05$, $df=90$). Consequently, fork length data are presented separately for fish caught with mesh sizes of 4" and 4.5 " for silvers but data for both meshes are pooled for spawning females and spawning males.

TAG RETURNS

The proportion of tagged fish in the monitors' harvests in the year following tagging (separately by site; Table 3) was on average 4.3% of the harvested fish at Big Eddy and Husky Channel, and 7-8% at Rat River and Destruction City. These data formed the basis of the mark-recapture estimates described in Sandstrom and Harwood (2008). Tag recaptured fish caught by the monitors were included in the dead sample wherever possible, for examination of sequential spawning and growth of individuals between tagging and recapture. Harvest totals and numbers of marked and unmarked fish that were caught by the monitors were used in the population estimates. Harvests and tags turned in by other fishers were recorded but were not included in the mark recapture calculations.

BIOLOGICAL INDICATORS

Sampling of the Dolly Varden harvests at the monitoring sites (1995-2007) (Fig. 2) provides a long-term record of size, sex, age and condition of Dolly Varden taken in the fishery. A truncated length-frequency distribution, a decrease in the number of large fish, or changes in age structure could indicate a downward trend in the stock.

FORK LENGTH

Dolly Varden monitors recorded the fork length of 5799 Dolly Varden from this fishery between the years 1995 and 2007 (current-year female spawners, n=1043; current-year male spawners n=385; silvers n=4371). The largest fish caught in the fishery during this period was a current-year spawning male, 724 mm and 3900 g, caught using 114 mm mesh net at the mouth of the Rat River in August 2004. The percent of Dolly Varden with fork length >550 mm averaged 10% for the period 1995-2007. The proportion varied over the series (Table 4) and in 2007, is similar to that observed in 1995 when the monitoring study was initiated.

The mean fork lengths (± 1 SD) of current-year female and male spawning Dolly Varden caught in this fishery, by site and year, are shown on Fig. 7. The data are not

separated according to mesh size as no significant differences in mean length were found for these two sex/maturity groupings based on mesh size. Mean fork length of current-year spawning females (Fig. 7) showed an increasing trend from 1997-2006. This trend was also apparent in the length-frequency distribution for spawning males (Fig. 7) and for current-year spawning females sampled at the Fish Hole during the assessment project (Sandstrom et al. 2009). The mean fork length of silvers remained relatively unchanged for both mesh sizes throughout 2001-2007 when mesh sizes were available for all dead-sampled fish (Fig. 8). This pattern is also apparent from the length-frequency distributions shown on Fig. 9.

The mean annual fork lengths of silvers ($F=21.64$, $df=13, 1465$, $p>F<0.0001$), current-year spawning females ($F=4.17$, $df=13, 378$, $p>F<0.0001$) and current-year spawning male ($F=3.01$, $df=12, 80$; $p>F=0.0016$) were significantly different among years. The Duncan's Multiple Range test revealed three groupings for mean size for each of current-year non-spawners, current-year spawning females and current-year spawning males during 2001-2007. The interaction of year and mesh size was evaluated using t tests in PROC GLM and no significant interactions were identified for any of the sex/maturity groupings ($p>0.05$).

For female spawners, the direction of the trend was the most obvious. There has been a significant increase in mean fork length in recent years, with 2006 and 2004 in the grouping with the greatest mean length (Duncan's Multiple Range test, $p<0.05$). Male spawners and silvers showed a similar increasing trend up to 2005. Sample sizes for all groupings in 2006 and 2007 were small due to the harvest restrictions in place (Table 5).

AGE AND MORTALITY

The oldest Dolly Varden caught in the 1995-2007 subsistence fishery was 11 y, while the youngest was 2 y. Of all Dolly Varden aged as part of this study, 67.2% (n=3227) were either 5 y or 6 y. Modal age was 6 y and mean age was 5.8 y (n=4805).

The mean ages of Dolly Varden caught in the fishery differed between 1995-2007 for current-year non-spawners ($F=28.78$, $df\ 12, 3548$; $p>F<0.0001$), for current-year female spawners ($F=4.68$, $df= 12, 866$; $p>F<0.0001$) and for current-year male spawners ($F=3.93$, $df=12, 318$; $p>F<0.0001$). Mean ages for silvers, current-year spawning females and current-year spawning males for 2006 and 2007 were all in the lowest respective Duncan groupings (Fig. 10) and, in the case of silvers and current-year male spawners, they had the lowest mean age values in the series (Table 5). Changes in the mean age of the catch can result when younger fish becoming increasingly vulnerable to the fishery over time (either through enhanced growth or increased prevalence in the run), thereby driving the mean age of the catch lower.

The age-frequency distributions are also instructive and showed no clear shift in either direction of the age structure of the catch over time (Figs. 11, 12, 13). There was weak representation of the older age classes throughout all years of the study. There was an

apparent increase in the proportion of 4 y olds (smolts) in 2005-2007. The modal age remained at 5 or 6 y throughout the study, with the exception of a shift downward by one year in 2006 and 2007, and were not due to any change in fishing gear.

Instantaneous mortality rate calculated from the catch curve, ranged from a low of 0.54 in 2007 to a high of 1.41 in 1997 (Table 6).

LIFE HISTORY COMPOSITION, SEX RATIO AND MATURITY

The sex ratio of the catch remained stable throughout the 13 y of the monitoring program. On average, 37.8% were males (range: 32-46%). There were no obvious changes over time in the sex ratio of the catch (Table 4).

Silvers are caught more often than spawners in this fishery (Table 4) and females outnumber males by approximately 2 to 1 (Table 4). The annual proportion of silvers caught in the fishery averaged 75.4% between 1995 and 2007, ranging from a high of 92.9% in 1998 to a low of 54.2% in 1999.

Current-year spawning males (anadromous males) continue to be few in number in this fishery. Although the sex ratio has remained relatively stable throughout the 13 y of monitoring (30-40%), the proportion of anadromous males caught in this fishery has remained low throughout with the exception of 1999 (Table 4).

SOMATIC CONDITION

The condition of the upstream migrants reflects the quality and quantity of food available during summer feeding in the ocean and, as such, changes in condition are not considered to be direct responses of the stock to harvesting.

During 1995-2007, the average weight for a Dolly Varden was 1,274 g, or about 2.8 lb. The maximum weight of a Dolly Varden recorded by the monitors was 5,498 g (12.1 lb). Mean K for the series was 1.2 and range was 0.9-1.7 (Table 4). Mean condition indices varied among years and the differences were highly significant ($F=301.23$, $p>F<0.0001$). Dolly Varden had significantly higher condition indices in 1997, 1998, 2004 and 2007, compared with all other years in the series ($p<0.05$; Duncan's Multiple Range test).

GROWTH

Mean fork length-at-age for sex/maturity groupings pooled (Table 7; Fig. 14) has increased overall over the course of this monitoring study. Tag-recaptured Dolly Varden have shown high growth rates (Sandstrom et al. 2009) during this period. Examining mean length-at-age separately for the sex/maturity groupings revealed the same trend in each (Figs. 15, 16, 17). The trend toward increased length-at-age is most obvious among current-year female spawners but is also evident in all males and in silvers.

This analysis focuses on current-year spawning females to reduce variability and control for unbalanced design. In addition, the female spawners provide adequate sample sizes as well as having a strong link to management implications. Mean length-at-age for female spawners, up to and including 2005, is summarized in Fig. 18.

Data from all monitoring sites have been pooled in order to provide adequate sample sizes for the analysis. However, sites/years with less than 20 current-year spawning females sampled were not used for the analysis as samples were deemed too small to be representative (Table 8).

The length distribution of female spawners sampled in the harvest approximates the same range of sizes and shape of the curve of the actual length distribution of the spawning population (Fig. 19). The latter was obtained through seining at the Fish Hole spawning and over-wintering site from 1995-2007 (Sandstrom et al. 2009). These two independent programs (different time of year/location/gear) indicate similar trends, supporting our assumption that samples >400 mm obtained from the harvest are not biased by gear selectivity.

The harvest is reasonably well distributed (and proportionately so) across the size range of the population. This supports our earlier observations of a stable age distribution (Figs. 11-13). Another possible explanation for the increase in size of the fish could be that the high harvest levels in 1997 and 1998 reshaped the age distribution. However, this apparently was not the case as evidenced in the age frequency distributions which remained relatively unchanged through the monitoring time series (Figs. 11-13).

Another possible explanation for the apparent increase in size of fish in the fishery in recent years is the effect of changing gear. However, our earlier analysis of mesh size effects did not show this to be the case. There were no significant differences in mean length of female spawners caught using the mesh sizes ranging from 102-140 mm ($p>0.05$). The majority of the harvest was caught using 102 mm (62%) and 114 mm (36%) mesh nets.

We also considered that an increase in mean size-at-age could be the result of an increase in the interval between spawning years, with fish thereby allocating increased resources to somatic growth each year. Our tagging results suggest that this is likely not the explanation, however, as rates of sequential spawning were unchanged (Table 9) during the slow growth period (e.g., 1995) vs the faster growth period (e.g., 2005) (Sandstrom et al. 2009). Dolly Varden growth is presently 20 mm /y greater than that recorded a decade ago (an increase of 74%; Fig. 21).

The data supports that Dolly Varden have a greater fork length at a given age than was the case a decade ago (Fig. 14). This was found to be the case for spawning females aged 5, 6 and 7 y (Fig. 20) as well as for all males and for all silvers as presented

earlier. Further, the mark recapture data (Sandstrom et al. 2009) demonstrates that the increase in annual growth is equal across all sizes, with all size classes growing at the same rate (Fig. 22). This suggests that the effect is not density- dependant, but rather an environmental effect. There were significant differences in the length-weight relationship among years of the study but no obvious trend over time in these changes in condition (Table 4).

The apparent increase in growth rates is unlikely due to a density-dependent effect brought about by a decline in population size. Available literature, including weir studies, suggest that the Dolly Varden feed little or not at all during migrations or while in freshwater (Sandstrom et al. 1997; Sandstrom and Harwood 2002). These fish feed primarily in the ocean during the summer. It is probable that food availability in the ocean is not a limiting factor.

An analysis of the date of clearing of the land-fast ice (H. Melling, Institute of Ocean Sciences, 2008) has provided instructive data as to the changes that are occurring in the Beaufort Sea with regard to the timing of break up of the land-fast ice each spring. Changes in climate (Walsh 2008) have led to earlier break up of the annual sea ice in the Beaufort Sea since the 1980's, however, variability has increased as well.

The plot illustrates the relationship between mean annual fork length of female spawners and date of ice clearing (days past June 1) (Fig. 23). Residuals for somatic condition index (K) and date of ice clearing are plotted on Fig. 24. The relationship between an earlier timing of break up and increased K is clear (R^2=0.4466).

With a trend toward earlier break up of the land-fast ice in the Beaufort Sea, oceanographic conditions which favor the production of zooplankton are established earlier in the season than was the case a decade ago. Thus, feeding opportunities for Dolly Varden occur earlier in the season. Earlier access to resources in the ocean and, possibly access to enhanced resources (climate change causes an increase in the marine pelagic community), are two plausible explanations for the apparent increase in growth rates of Dolly Varden observed during the past decade. Changes in the body condition of Arctic char (Harwood 2009) and ringed seals (Harwood et al. 2000) have been postulated as linked to changing ice conditions over the same time period.

The increased growth may result in a 30% increase in the reproductive output of this Dolly Varden stock (Table 10), assuming a length/fecundity relationship similar to other North Slope rivers (Sandstrom 1995). This may help to offset the negative effects of harvesting on reproductive potential when spawners are removed from the fishery.

SUMMARY

Annual changes in the biological parameters and the success of the fishery, monitored over an extended period of time, provide a means by which to assess the status of the stock and

the sustainability of the fishery. This monitoring program is only one of several Dolly Varden management initiatives underway by the harvesters of Fort McPherson and Aklavik, working with the Gwich'in Renewable Resources Board (GRRB www.grrb.ca), the Fisheries Joint Management Committee (FJMC www.fjmc.ca) and Fisheries and Oceans Canada.

The CPUE results in this study suggest the anadromous stock of Dolly Varden from the Rat River declined in the period from 2000-2002. The mark-recapture estimate which will follow the 2008 fishery, as well as the results from the 2008 monitoring study, will provide clues if this declining trend has continued or if the stock is recovering. Harvest restrictions in place since 2006 and recent observations at the Fish Hole (fall 2007), both suggest that the situation in regard to stock size has not deteriorated further than the 2004 data suggest.

Significant increases in the size-at-age over the time series, relatively stable sex and maturity composition, and the recent observed pulse of juvenile production at the Fish Hole in fall 2007 (Sandstrom et al. 2009) are all encouraging signs for this stock. The highly skewed sex ratio is of concern with regard to the abundance of sea-run males, as they remain in short supply. While this is not likely a problem that can be corrected through management practice, it is advised that fishers release live sea-run males as often as possible to ensure their continued contribution to the reproductive potential of the stock.

The following are highlights of, or relating to, this work:

- One or more stocks of anadromous Dolly Varden, known locally as "char", inhabit the Rat River and its tributaries.
- Fishermen from two adjacent land claim groups, the Gwich'in and the Inuvialuit, harvest Dolly Varden from the Rat River stock(s).
- Communities of Aklavik and Fort McPherson developed and implemented their "Rat River Char Fishing Plan" in 1995; this has continued until present.
- The fishery has been monitored through a 3-5 site community-based sampling program, 1995-2007.
- Over 98% of the fish caught and monitored in this study were caught using 102 mm (4") or 114 mm (4.5") mesh nets.
- There were no significant differences in mean fork length due to mesh size for spawning females or spawning males.
- Mean fork length of silvers caught with 114 mm (4.5 ") mesh were significantly larger than those caught with 4.0" (102 mm) mesh.

- Declines in CPUE were apparent at all sites starting in 2000-2002, after which time the CPUE remained at a low level at all sites through to 2006, with a slight improvement in 2007.
- These declines in CPUE parallel the decline in stock-size estimates provided by the mark-recapture efforts.
- Silvers are caught more often than spawners in this fishery (approximately 3 to 1), and this has remained relatively unchanged over time.
- Females outnumber males (approximately 2 to 1) in this fishery, and this has remained relatively unchanged over time.
- Anadromous males remain at a low level in the stock, and this has remained relatively unchanged over time (present proportion is similar to 1995).
- Through to 2005, there was an increase in mean length of female spawners over time; there was a similar although less pronounced trend in male spawners and silvers over the same period; there has been a slight decrease in mean length in 2006 and 2007 which was likely due to increased prevalence of younger fish in the catches in 2006 and 2007.
- Modal age remained at 5 or 6 years throughout the study, with the exception of a shift downward by one year in 2006 and 2007.
- Age-frequency distributions showed no clear shift in either direction of the age structure of the catch over time.
- There was weak representation of the older age classes throughout all years of the study.
- There was an apparent increase in the proportion of 4 y olds (smolts) in 2006-2007.
- Rat River Dolly Varden have greater fork length at a given age than was the case a decade ago.
- These increases in growth rate and an increase in somatic condition in certain years, appear related to the timing of break up of the sea ice.
- Timing of break up may influence the timing of the zooplankton bloom and thus, the Dolly Varden's access to quantity and quality of prey.
- Increased growth of individuals in the stock provides increased biomass to the fishery and, to a point, may offset the pressure of the fishery on the reproductive potential of the stock through the practice of catching spawners.

ACKNOWLEDGEMENTS

The work and dedication of the monitors, Selwyn Kay (19 years), the late Joe Vittrekwa (3 years), Lazarus Francis (1 year), Billy Wilson (7 years), John Carmichael (13 years), Ben Mitchell (6 years) and Dale Semple (3 years) is duly acknowledged. The staff of the Fort McPherson and Aklavik RRCs assisted with program administration. The data have been collected with the enthusiastic support of the RRCs and the people of Aklavik and Fort McPherson, who allowed their catches to be enumerated and sampled. We greatly appreciate the efforts of Lothar Dahlke (DFO) for coordination of the monitoring study prior to 1995.

All of the Dolly Varden were aged by Gary Carder, formerly of DFO, presently of Salmon Arm, BC. Ian McLeod assisted with program delivery in 1996. Julia Kenyon did all the data entry and proofing since 1999. We thank Dr. Jim Reist (DFO) and Ms. Kelly Withers (DFO) for helpful reviews of the manuscript. The work was funded by the Gwich'in Renewable Resources Board and by DFO.

LITERATURE CITED

Aklavik RRC, Fort McPherson RRC and Aklavik HTC. 2006. Rat River Char Fishing Plan. Available: Dept. of Fisheries and Oceans, Box 1871, Inuvik, NT Canada, X0E 0T0.

Anderson, R.O., and Gutreuter, S.J. 1983. Length, weight and associated structural indices. *In* Fisheries Techniques. Edited by L.A. Nielsen and D.L. Johnson. American Fisheries Society, Bethesda, Maryland. pp. 283-300.

Clark, I.D., Lauriol, B., Harwood, L. and Marschner, M. 2001. Groundwater contributions to discharge in a permafrost setting, Big Fish River, N.W.T., Canada. Arctic, Antarctic and Alpine Research, Vol. 33(1): 62-69.

DFO. 2001. Rat River Dolly Varden. DFO Science Stock Status Report D5-61. Available www.dfo-mpo.gc.ca/csas

Gillman, D.V., and Sparling, P.D. 1985. Biological data on Arctic char, *Salvelinus alpinus* (L.).from the Rat River, Northwest Territories, 1983. Can. Data Rep. Fish. Aquat. Sci 535: iv + 15 p.

Harwood, L.A. 2001. Status of anadromous Dolly Varden (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through community-based sampling of the subsistence fishery, August-September 1989-2000. Canadian Stock Assessment Secretariat Research Document 2001/090. Department of Fisheries and Oceans, Ottawa, Ontario Canada. Available www.dfo-mpo.gc.ca/csas

Harwood, L.A. 2009. Status of anadromous Arctic charr (*Salvelinus alpinus*) of the Hornaday River, Northwest Territories, as assessed through harvest-based

sampling of the subsistence fishery, August-September 1990-2007. Can. Tech. Rep. Fish. Aquat. Sci. xxxx: vi + 44 p.

Harwood, L.A., Smith, T.G., and Melling, H. 2000. Variation in reproduction and condition of the ringed seal (*Phoca hispida)* in Prince Albert Sound, N.T., Canada, as assessed through a community-based sampling program. Arctic 53 (4): 422-431.

McDonald, I. 1998a. Gwich'in Harvest Study Data Report, August 1995-December 1996. Prepared by the Gwich'in Renewable Resources Board, Box 2240, Inuvik, NT Canada X0E 0T0.

McDonald, I. 1998b. Gwich'in Harvest Study Data Report, 1997. Prepared by the Gwich'in Renewable Resources Board, Box 2240, Inuvik, NT Canada X0E 0T0.

Nordeng, H. 1961. On the biology of char (*Salmo alpinus L.). In* Salangen, North Norway. 1. Age and spawning frequency determined from scales and otoliths. Nytt Mag. For Zool. 10: 67-123.

Reist, J.D. 1989. Genetic structuring of allopatric populations and sympatric life history types of char, *Salvelinus alpinus/malma*, in the western Arctic, Canada. *In* Biology of chars and masu salmon: Proceedings of the International Symposium on chars and Masu Salmon. Edited by H. Kawanabe, F. Yamazaki, and D.L.G. Noakes. Physiol. Ecol. Japan, Spec. Vol. 1: 405-420.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191. Dept. of Fisheries and Oceans, 200 Kent St., Ottawa, Ontario, Canada.

Sandstrom, S.J. 1995. The effect of over-wintering site temperature on energy allocation and life history characteristics of anadromous female Dolly Varden (*Salvelinus malma*), from north-western Canada. M.Sc. Thesis, University of Manitoba, Winnipeg, MB. 161 p.

Sandstrom, S.J., and Harwood, L.A.. 2002. Studies of anadromous Dolly Varden (*Salvelinus malma*) (W.) of the Big Fish River, NT, Canada 1972-1994. Can. Manuscri. Rep. Fish. Aquat. Sci. 2603. 31 p.

Sandstrom, S., Harwood, L., and Howland, K. 2009. Status of anadromous Dolly Varden charr (*Salvelinus malma*) of the Rat River, Northwest Territories, as assessed through mark-recapture and sampling at the spawning and over-wintering site (1995-2007). Can. Manuscr. Rep. Fish. Aquat. Sci. XXX: xx + p.

Sandstrom, S., Lemieux, P.J., and Reist, J.D. 1997. Enumeration and biological data from the upstream migration of Dolly Varden Char (Salvelinus malma) from the Babbage River, Yukon North Slope, 1990-1992. Can. Data Rep. Fish. Aquat. Sci. 1018. 132 p.

SAS (Statistical Analysis System). 1996. SAS Users guide: Statistics Version 6. SAS Institute Inc., Cary, NC.

Sokal, R.R., and Rohlf, F.J.. 1995. Biometry. Third Edition, W.H. Freeman and Company, California. 887 p.

Sparling, P.J., and Stewart, D.B. 1986. Data from the monitoring of domestic/ commercial fisheries for Arctic char in the Big Fish River and Rat River areas, Northwest Territories, 1986. Fisheries Joint Management Committee Report No.

86-002. 28 p. Available: FJMC, Box 2120, Inuvik, NT, Canada. Prepared by Arctic Biological Consultants, Pinawa, MB.

Stephenson, T., and Lemieux, P.J. 1990. Status of the Rat River char population, 1989. Fisheries Joint Management Committee (FJMC) Report No. 89-008. 62 p. Available: FJMC, Box 2120, Inuvik, NT, Canada. Prepared by Dept. of Fisheries and Oceans, Box 1871, Inuvik, NT Canada.

Walsh, J.E. 2008. Climate of the Arctic environment. Ecological Applications. Vol. 18 (2) Supp. S3-S22.

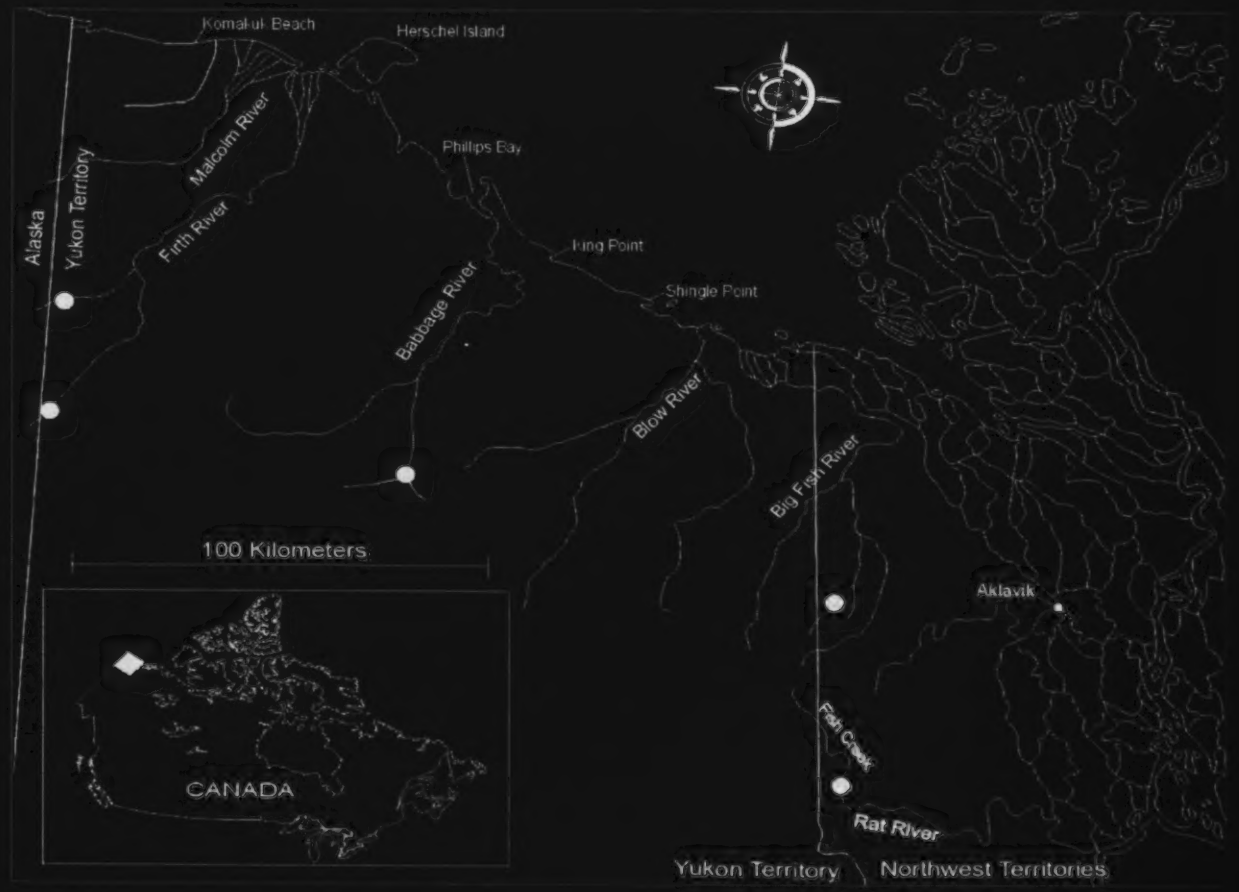


Figure 1. The Yukon North Slope showing the location of Dolly Varden rivers (known spawning locations denoted with black circle).

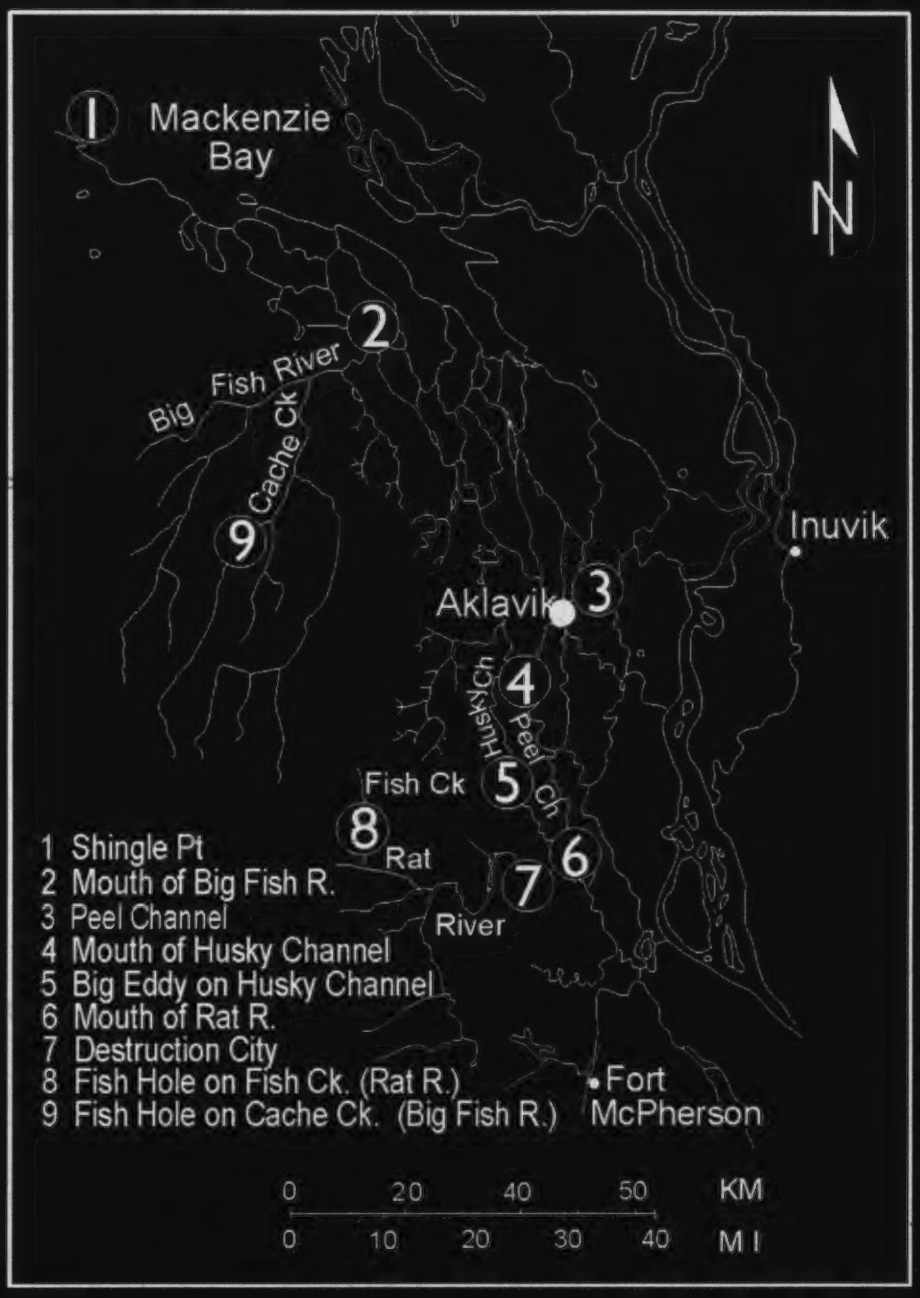


Figure 2. Rat River and Big Fish River Dolly Varden fishing and monitoring sites.

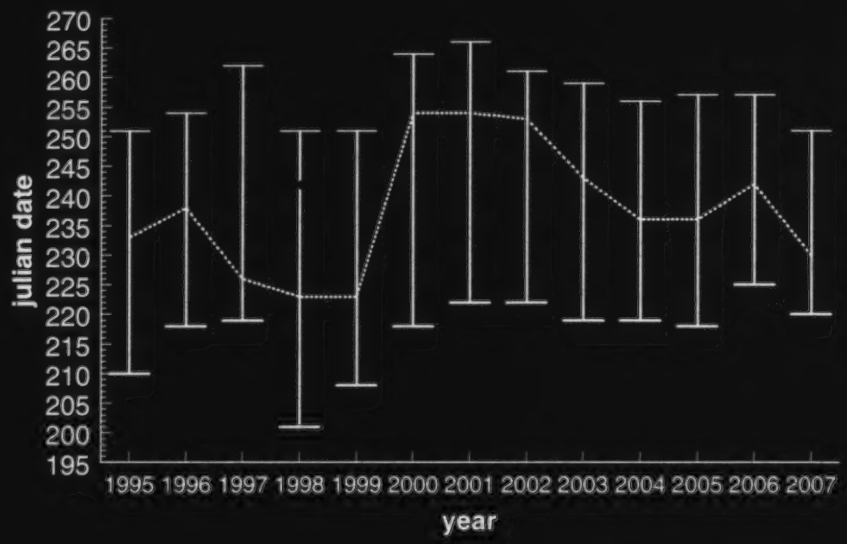
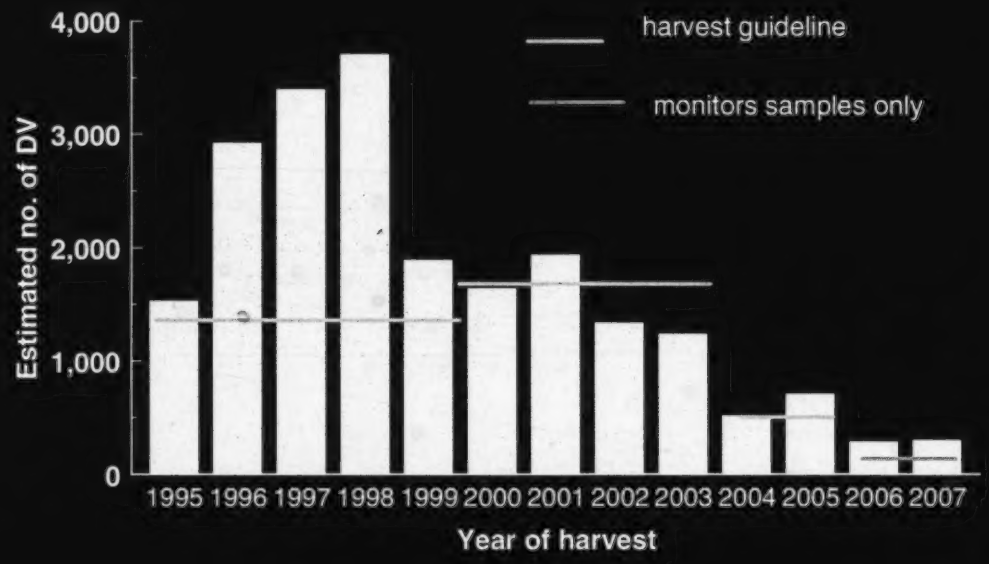


Figure 3. Timing (range and mode) of the Rat River Dolly Varden subsistence fishery, 1995-2007.



* data for Inuvialuit harvest of DV for all locations for 2000-2007 estimated and included at 150 per year for illustrative purposes

Figure 4. Estimated harvest of Rat River Dolly Varden (DV) from the subsistence fishery, 1995-2007.

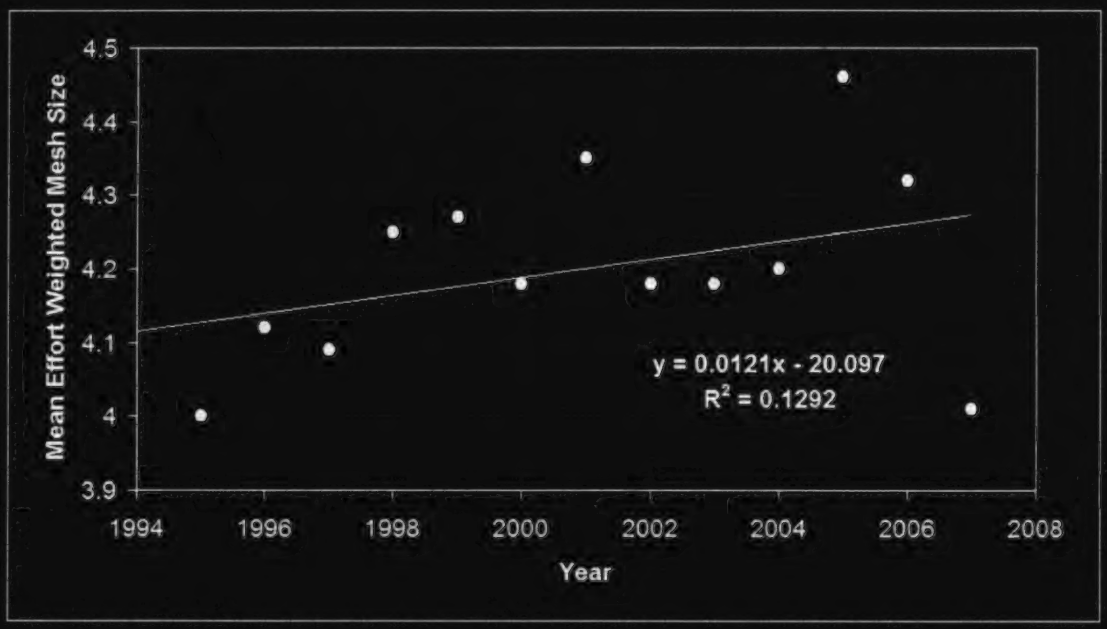
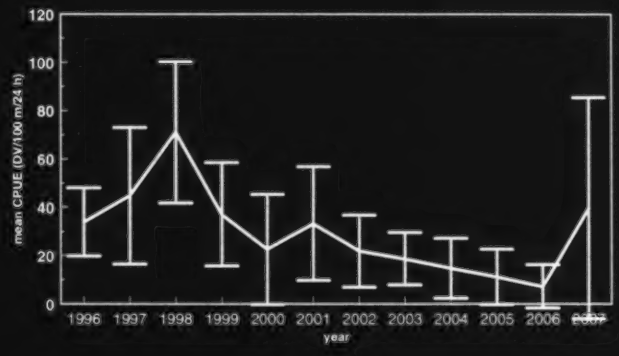
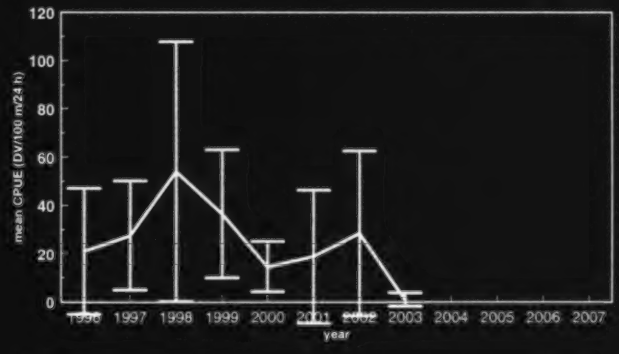


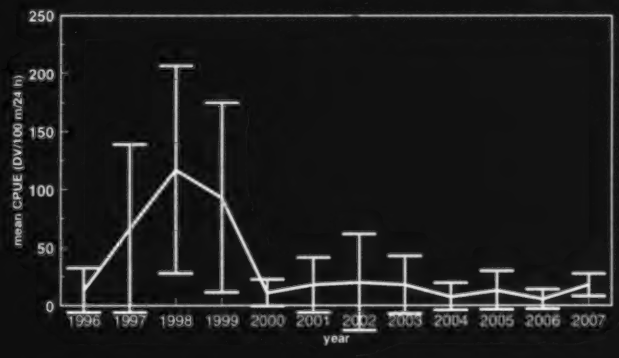
Figure 5. Mean effort-weighted mesh size vs year, Rat River Dolly Varden subsistence fishery.



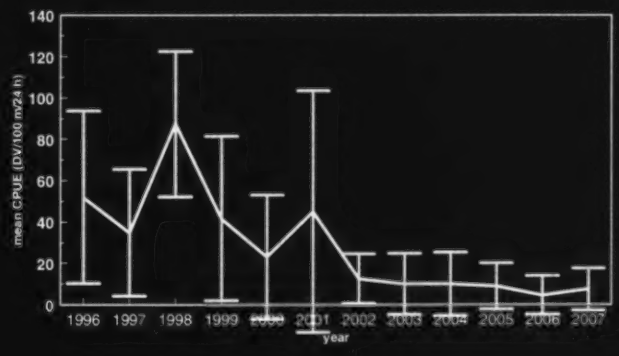
Mean CPUE (no DV/100 m/24 h) (± 1 SD) at Big Eddy, 1996-2007 (n=765 sets)



Mean CPUE (no DV/100 m/24 h) (± 1 SD) at Husky Channel, 1996-2003 (monitor not working beyond 2003)(n=477 sets)

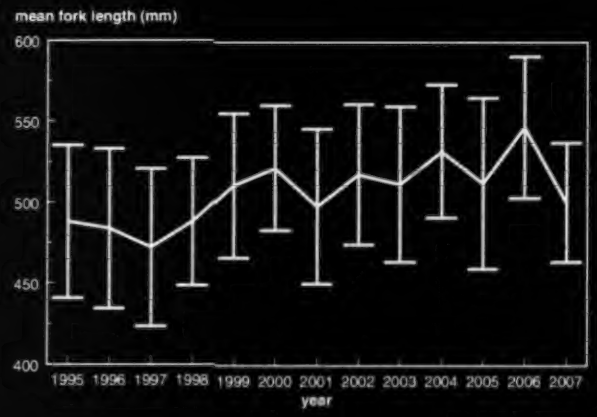


Mean CPUE (no DV/100 m/24 h) (± 1 SD) at mouth of the Rat River, 1996-2007 (n=871 sets)

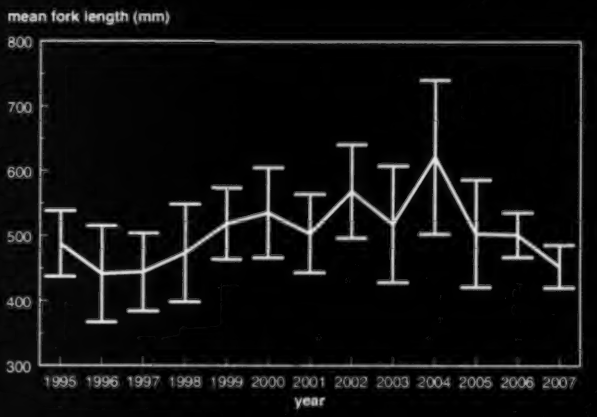


Mean CPUE (no DV/100 m/24 h) (± 1 SD) at Destruction City, 1996-2007 (n=1210 sets)

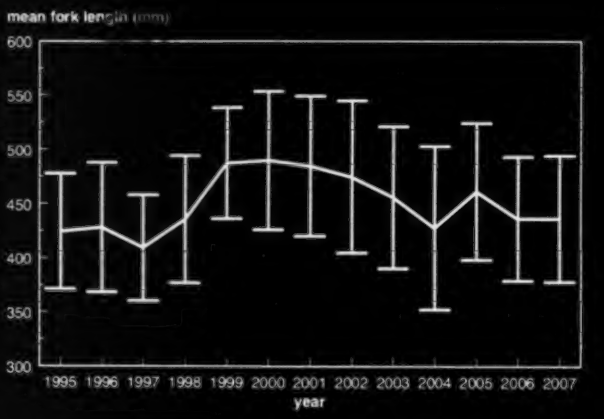
Figure 6. Mean CPUE for Dolly Varden (DV) at four monitoring sites, Rat River, 1996-2007.



Mean fork length (± 1 SD) of female spawner DV harvested, all sites, 1995 - 2007 (n=1043)

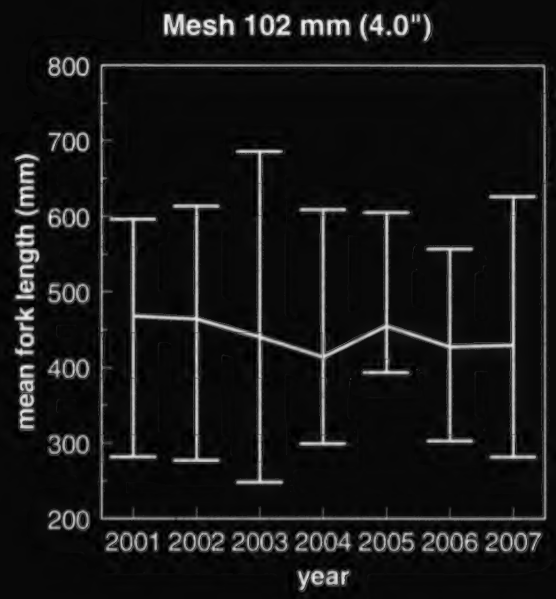


Mean fork length (± 1 SD) of male spawner DV harvested, all sites, 1995 - 2007 (n=385)

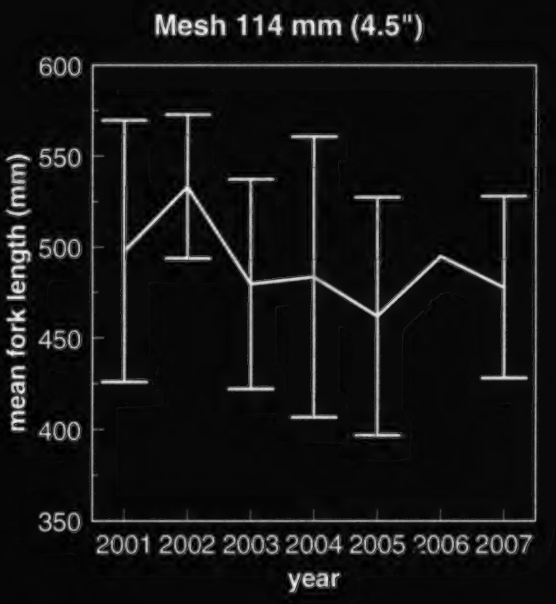


Mean fork length (± 1 SD) of silver DV harvested, all sites, 1995 - 2007 (n=4371)

Figure 7. Mean fork length of male and female spawning Dolly Varden (DV) caught at the Rat River subsistence fishery, 1995-2007.



Mean fork length (± 1 SD) of silver DV harvested using 102 mm mesh nets, all sites, 1995 - 2007 (n=937)



Mean fork length (± 1 SD) of silver DV harvested using 114 mm mesh nets, all sites, 1995 - 2007 (n=531)

Figure 8. Mean fork length of silver (current- year spawning Dolly Varden (DV) caught at the Rat River subsistence fishery, 1995-2007.

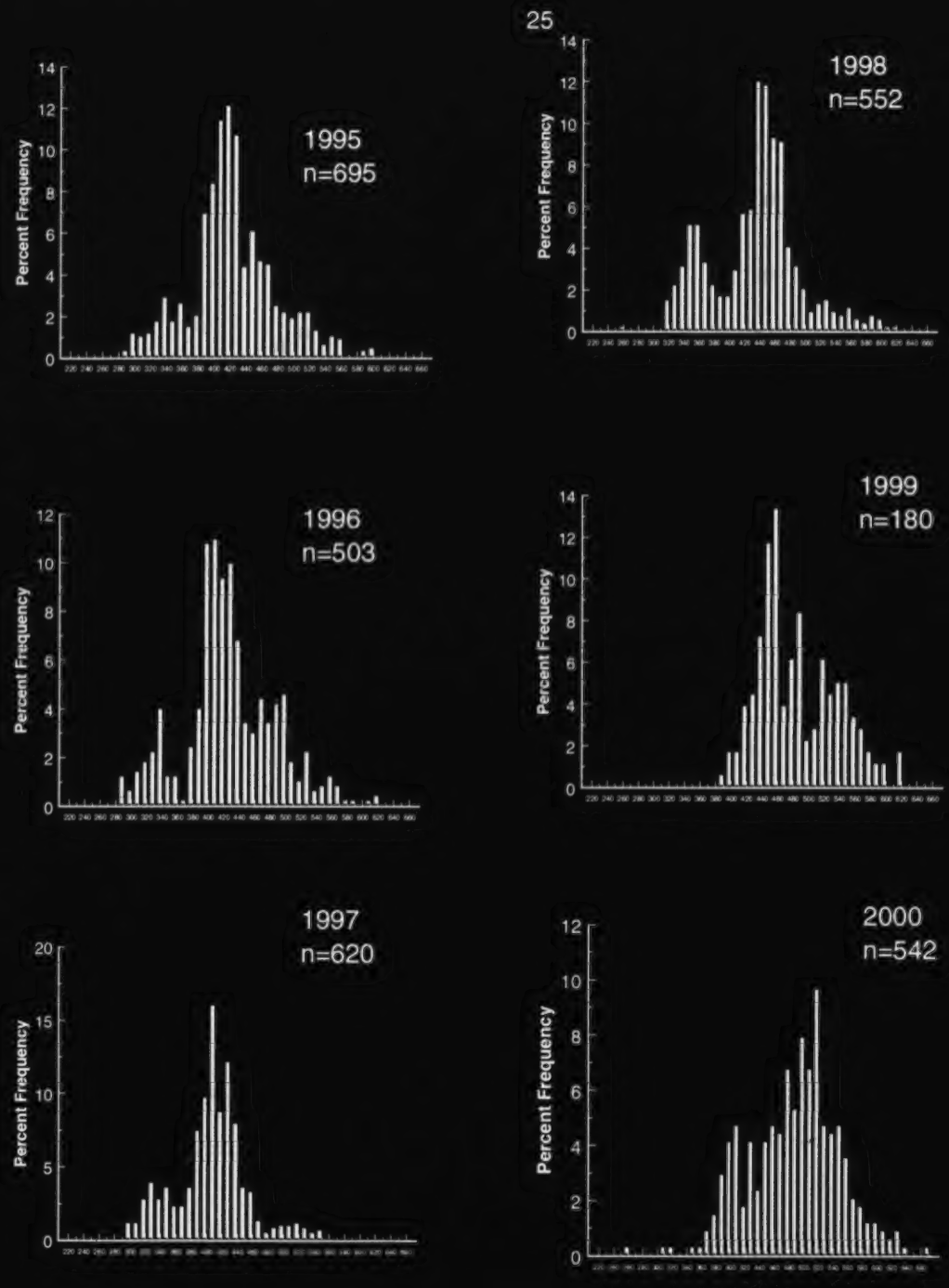


Figure 9. Size distribution of silver (current-year non-spawning) Dolly Varden caught in the subsistence fisheries at the community monitoring sites, 1995-2007.

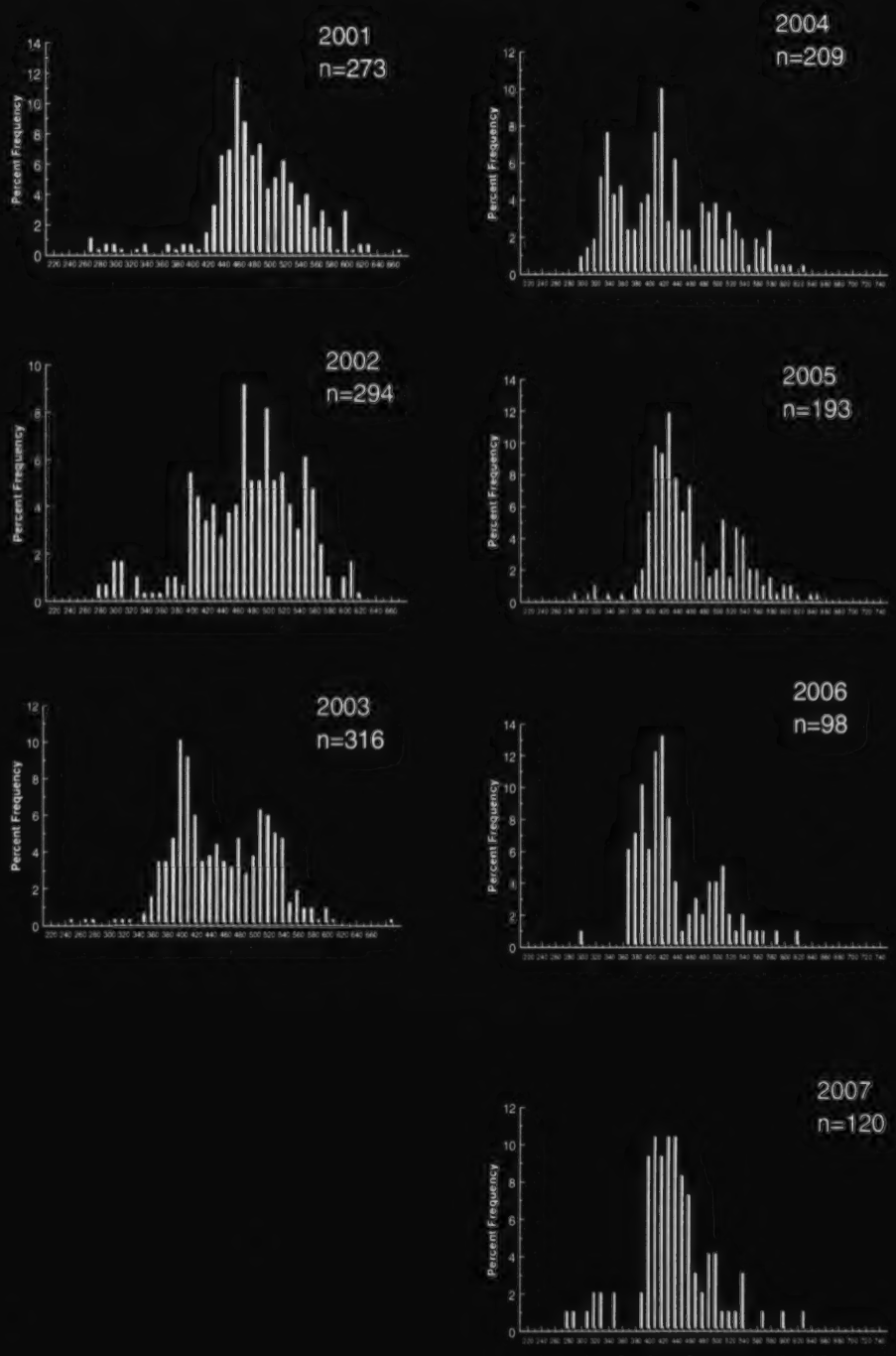
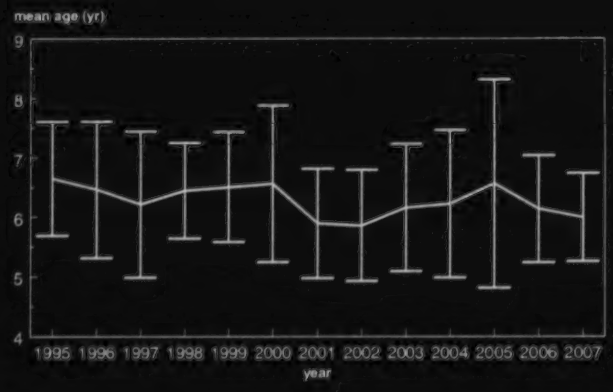
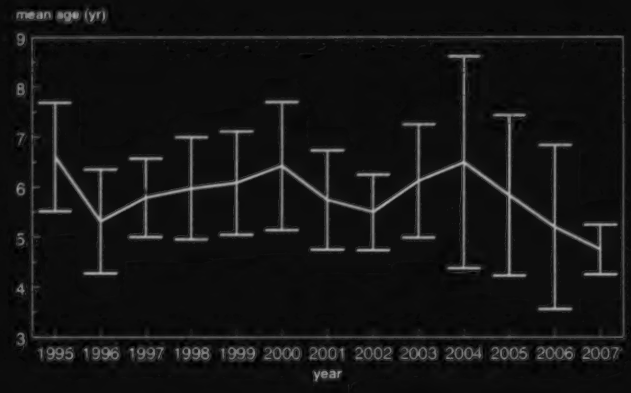


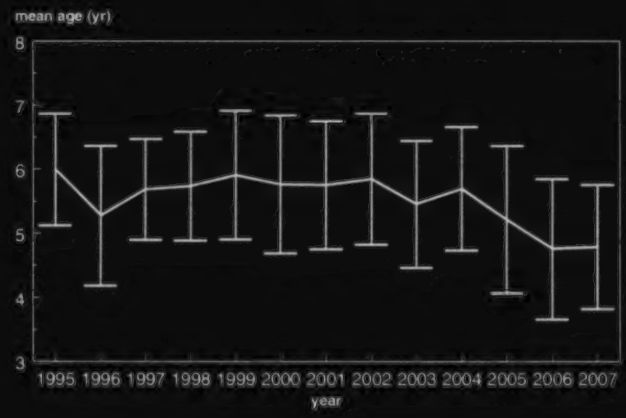
Figure 9. Cont'd.



Mean age (± 1 SD) of female spawner DV harvested, all sites, 1995 - 2007 (n=879)



Mean age (± 1 SD) of male spawner DV harvested, all sites, 1995 - 2007 (n=331)



Mean age (± 1 SD) of silver DV harvested, all sites, 1995 - 2007 (n=3561)

Figure 10. Mean age of male and female spawning Dolly Varden (DV) and silver Dolly Varden (DV) caught at the Rat River subsistence fishery, 1995-2007.

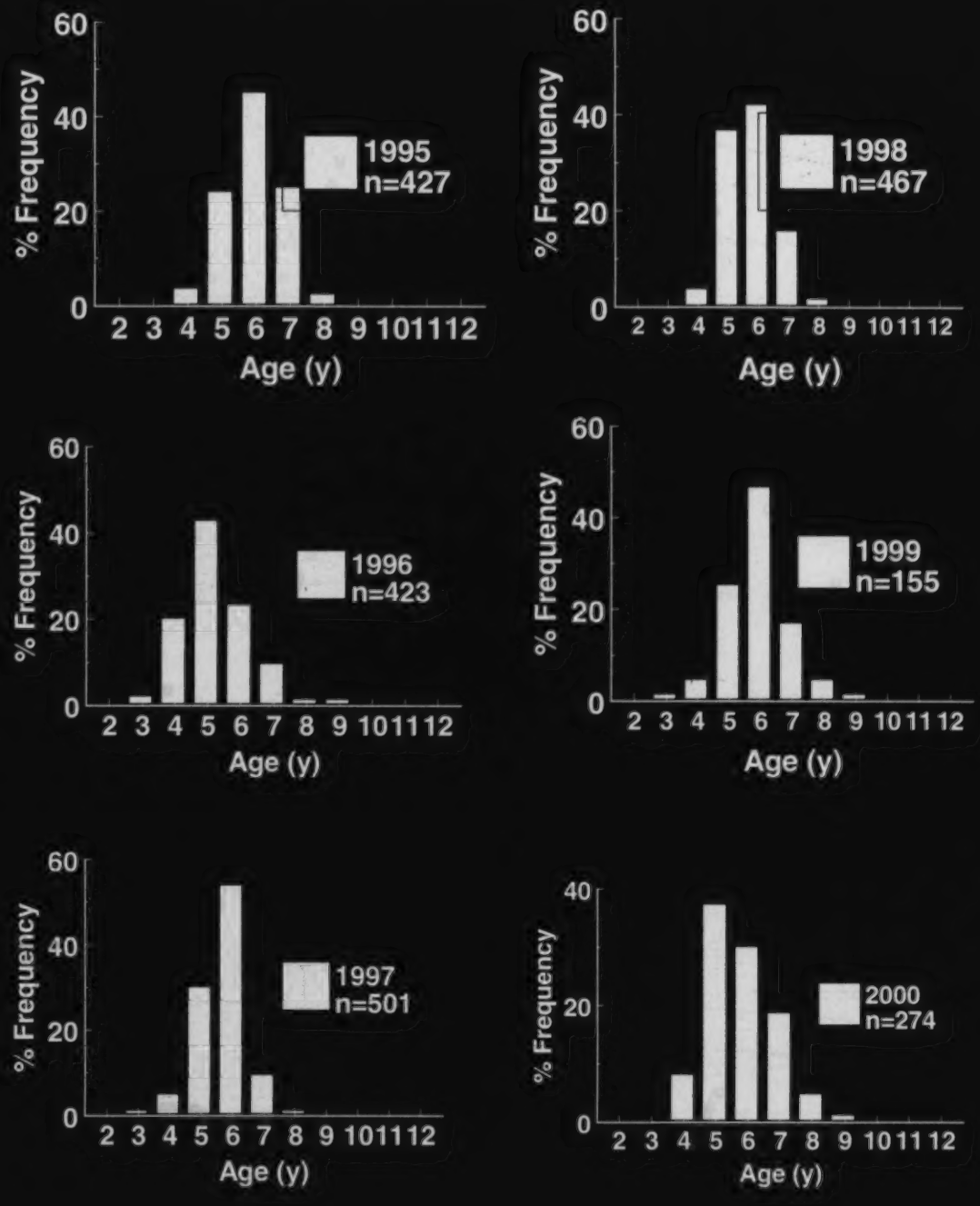


Figure 11. Age-frequency distribution of silver Dolly Varden caught in the subsistence fisheries at the monitoring sites 1995-2007.

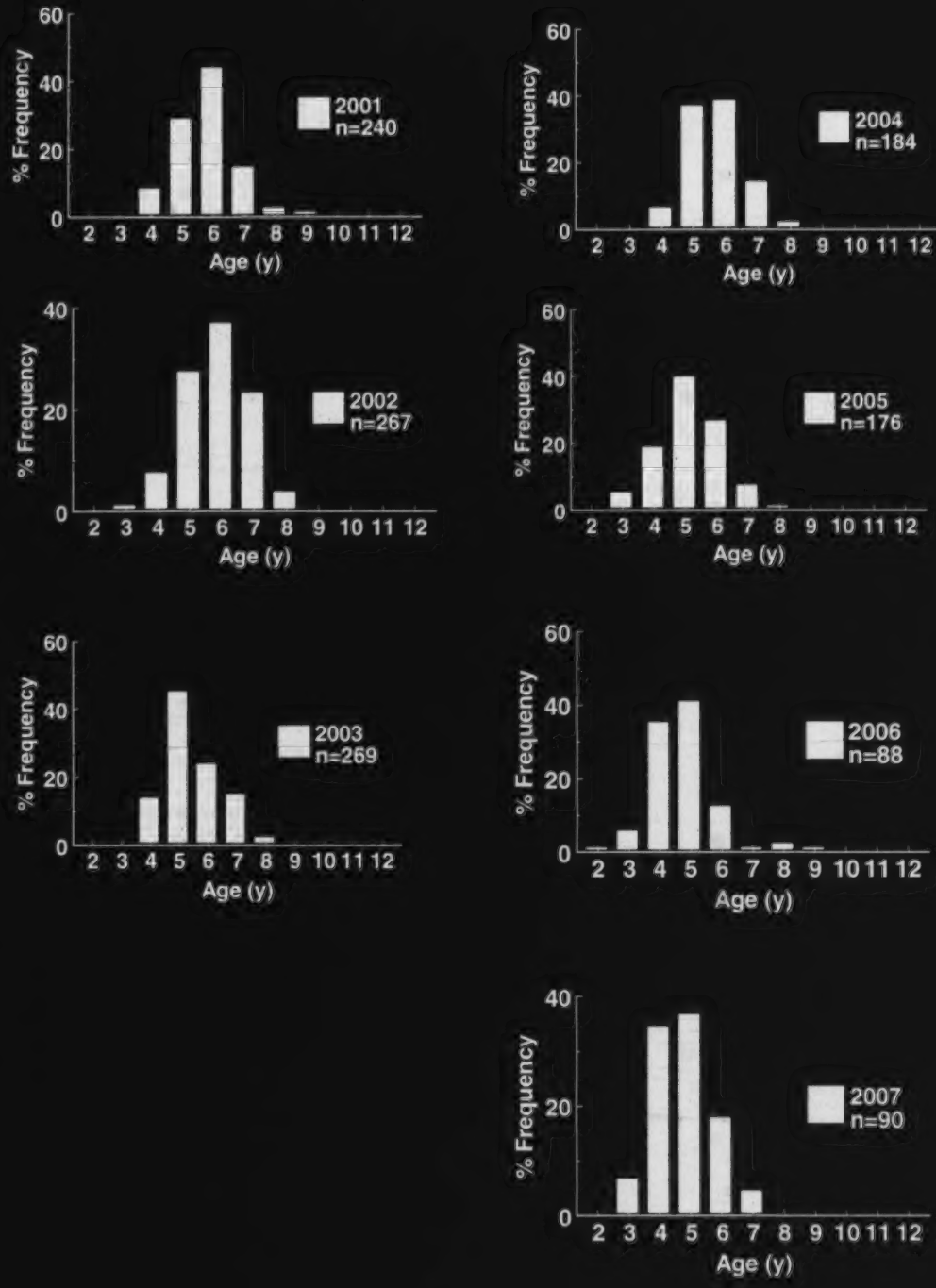


Figure 11. Cont'd.

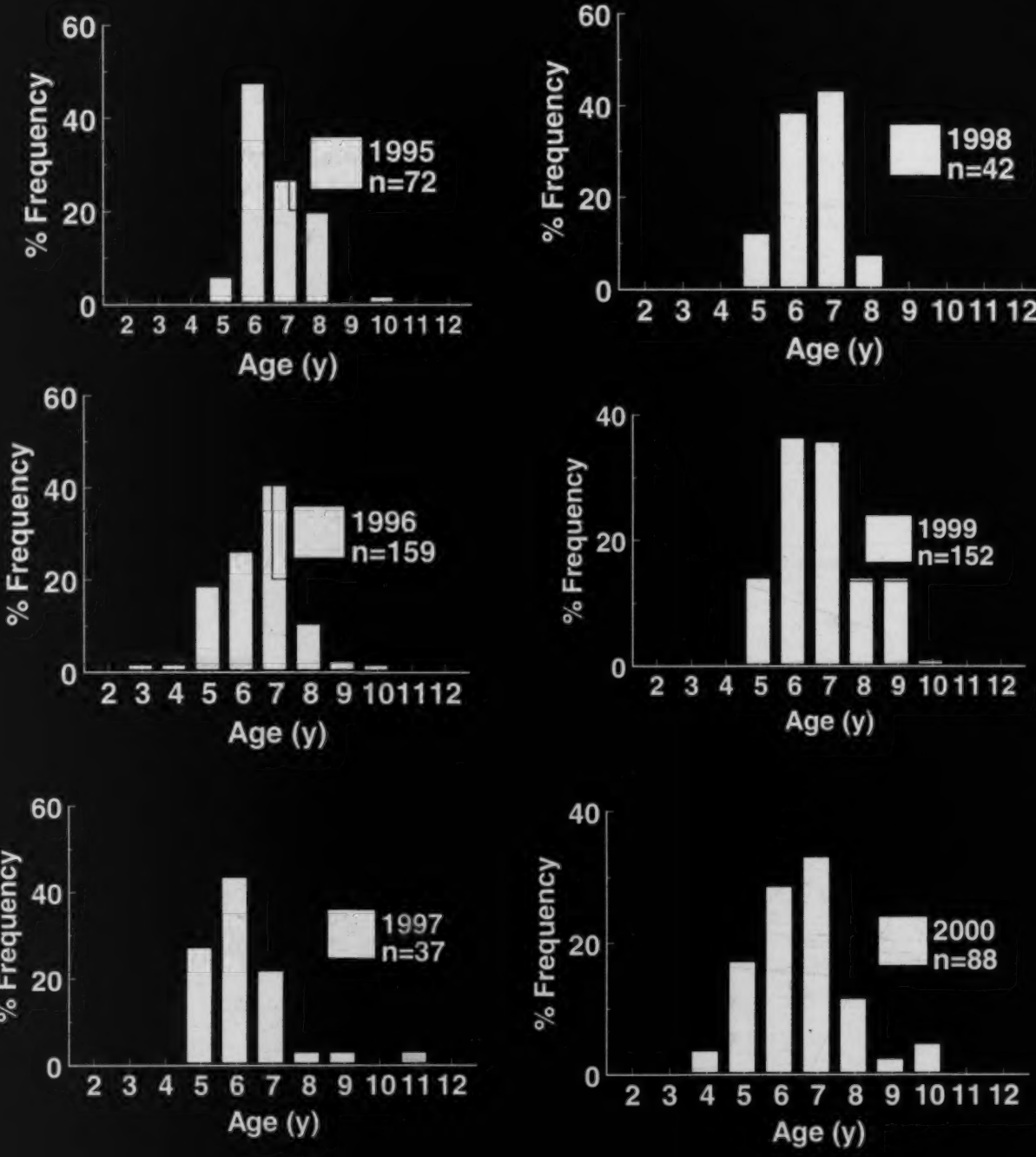


Figure 12. Age-frequency distribution of female current-year spawning Dolly Varden caught in the subsistence fisheries at the monitoring sites 1995-2007.

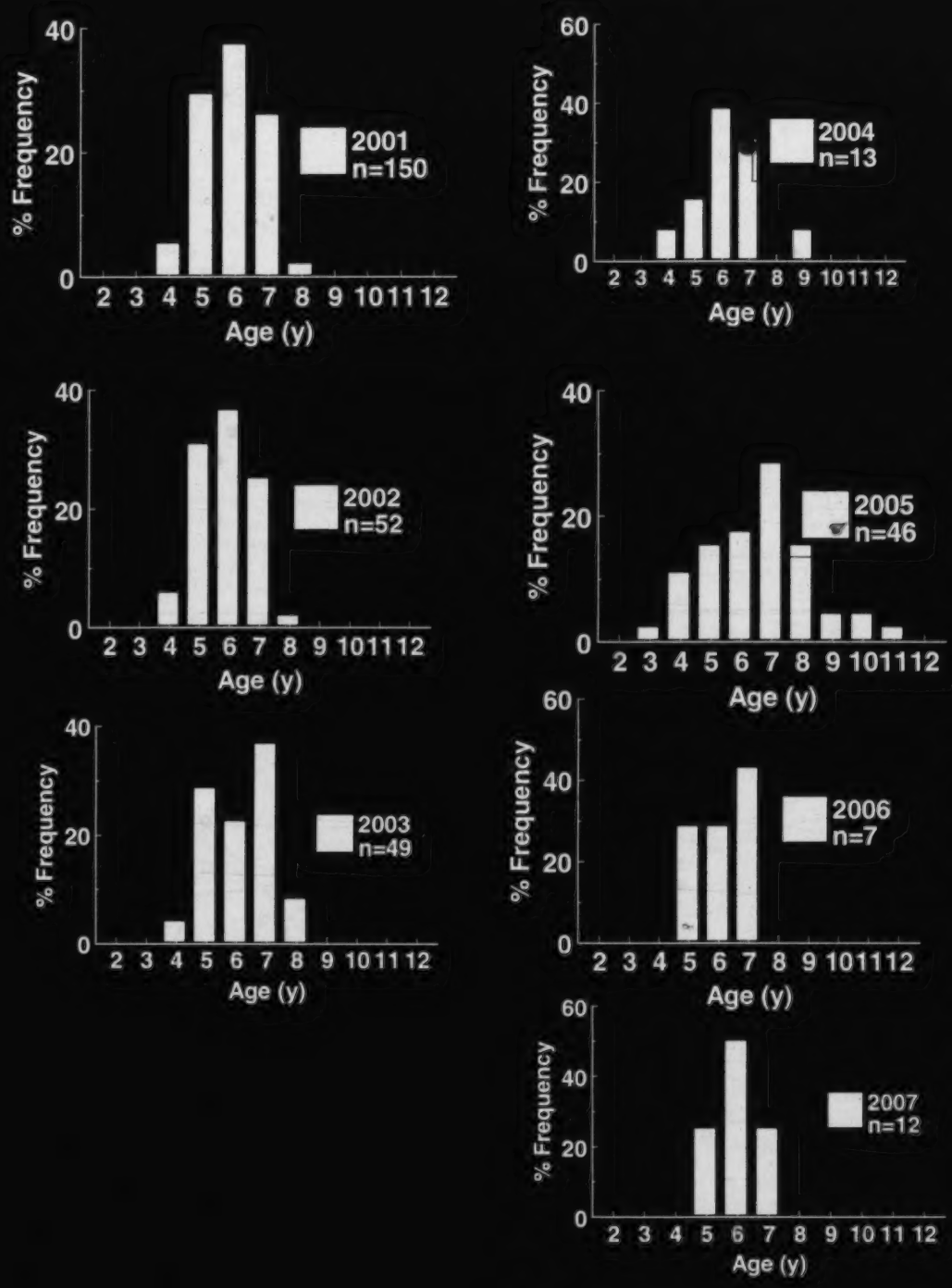


Figure 12. Cont'd.

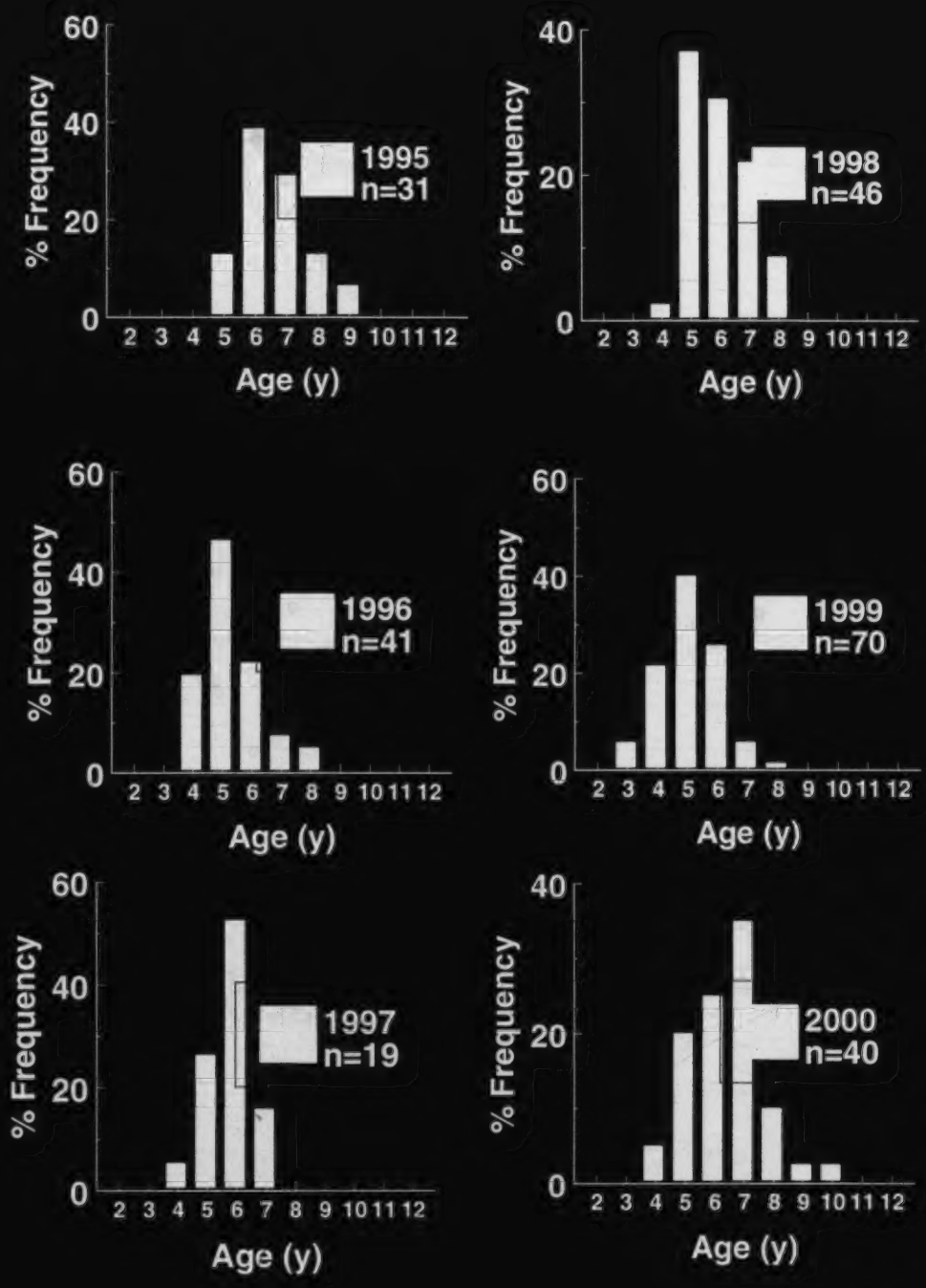


Figure 13. Age-frequency distribution of male current-year spawning Dolly Varden caught in the subsistence fisheries at the monitoring sites 1995-2007.

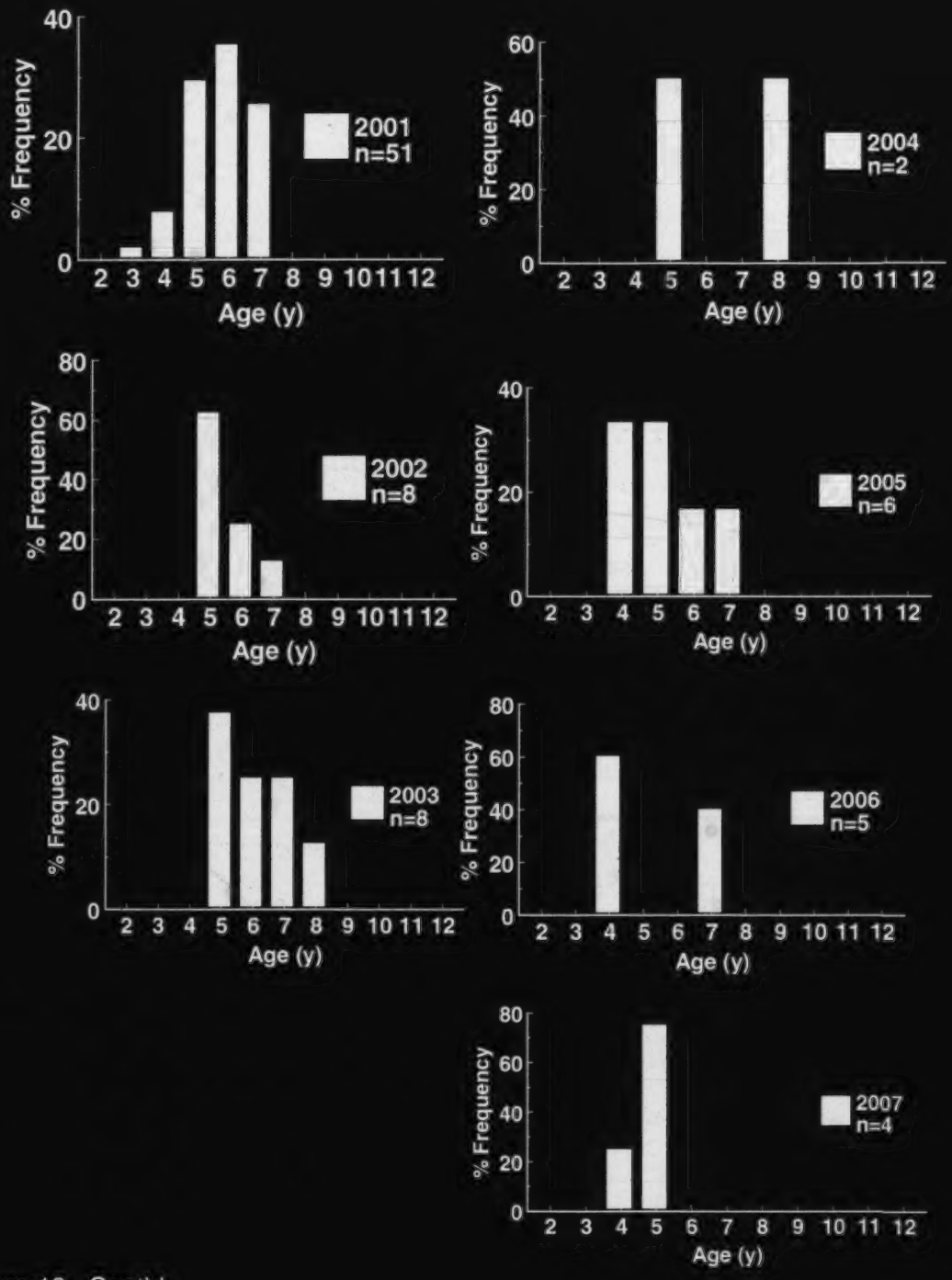


Figure 13. Cont'd.

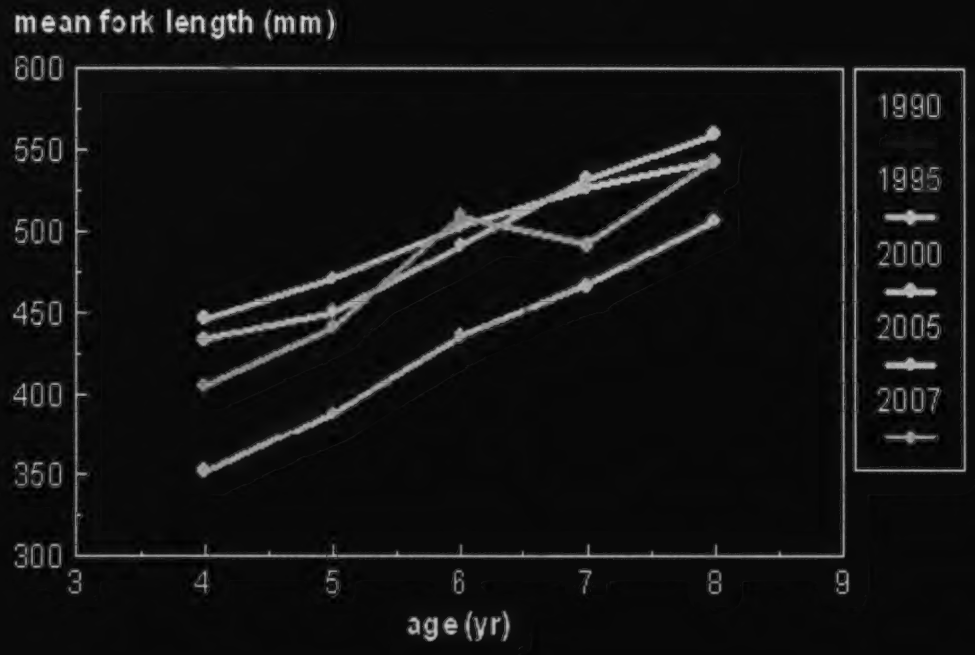


Figure 14. Mean size-at-age of Dolly Varden caught in the subsistence fishery in 1990, 1995, 2000, 2005 and 2007.

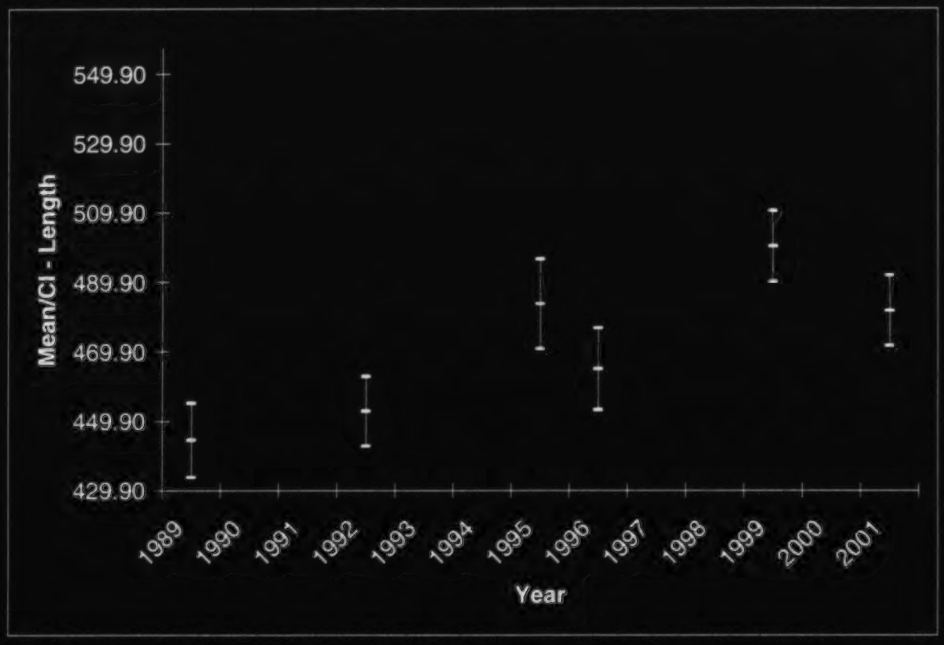


Figure 15. Mean fork length (mm) and confidence interval (CI) of 6-y current-year female spawning Dolly Varden, 1989-2001.

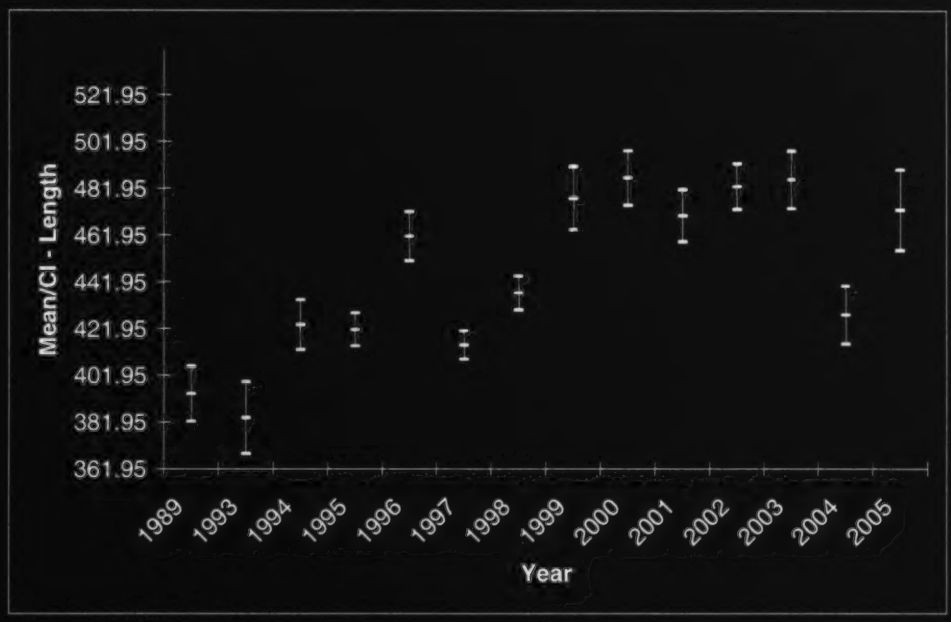


Figure 16. Mean fork length (mm) and confidence interval (CI) of 6-y female cuurent-year silver Dolly Varden, 1989-2005.

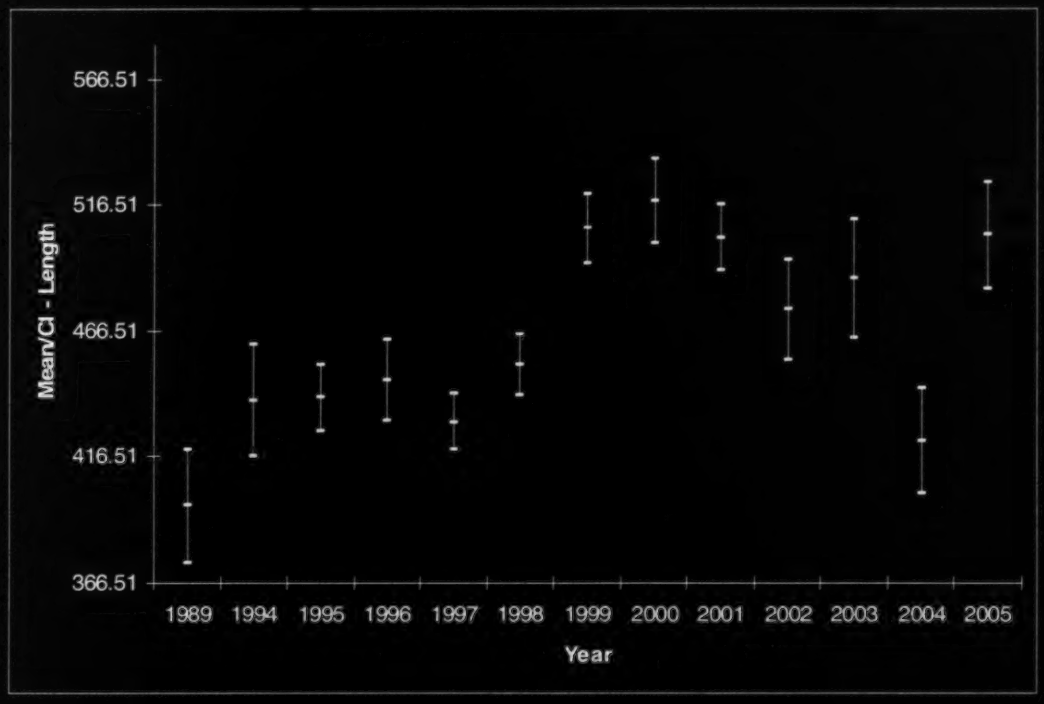


Figure 17. Mean fork length (mm) and confidence interval (CI) of 6-y male current-year silver Dolly Varden, 1989-2005.

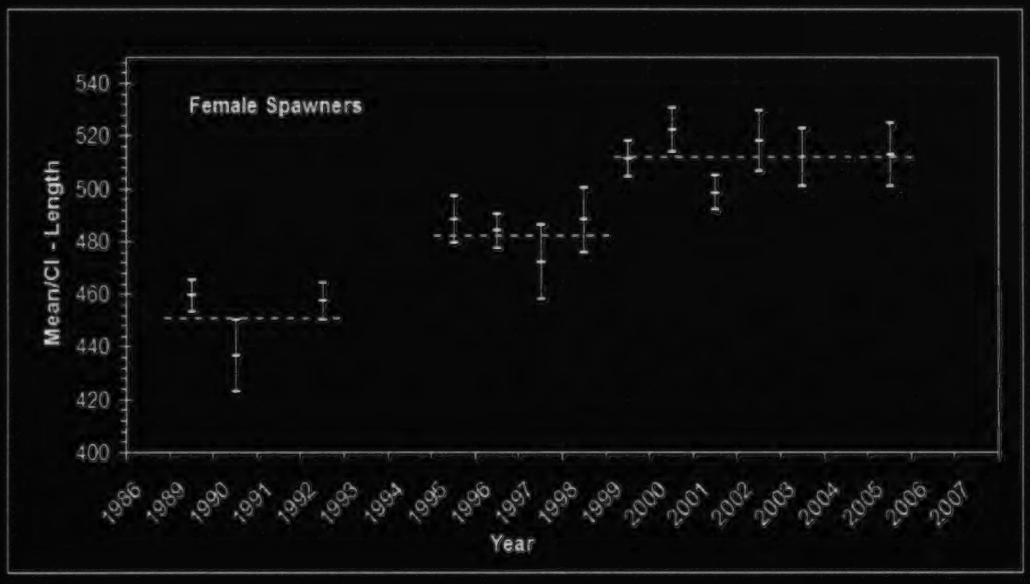


Figure 18. Mean fork length (mm) , confidence interval (CI) and trend line of current year spawning female Dolly Varden caught in the subsistence fishery, 1989-2005.

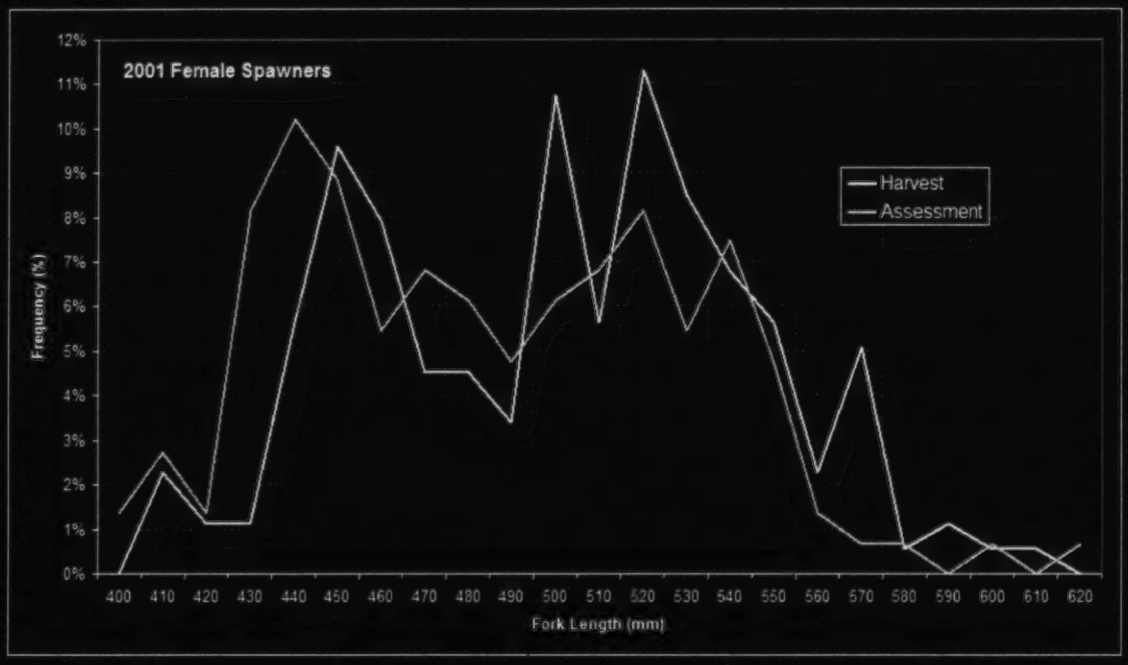
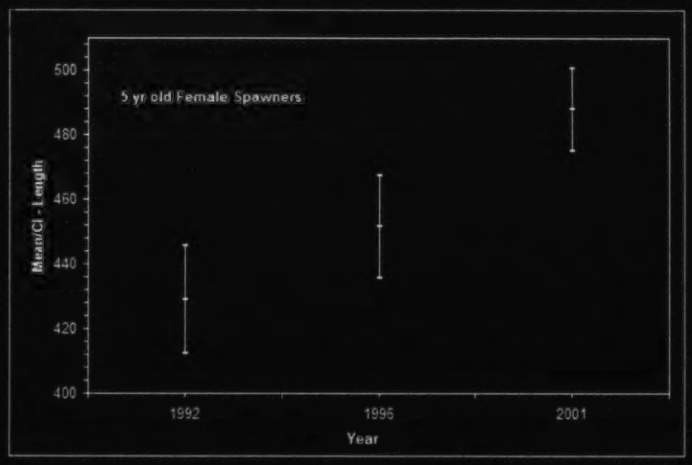
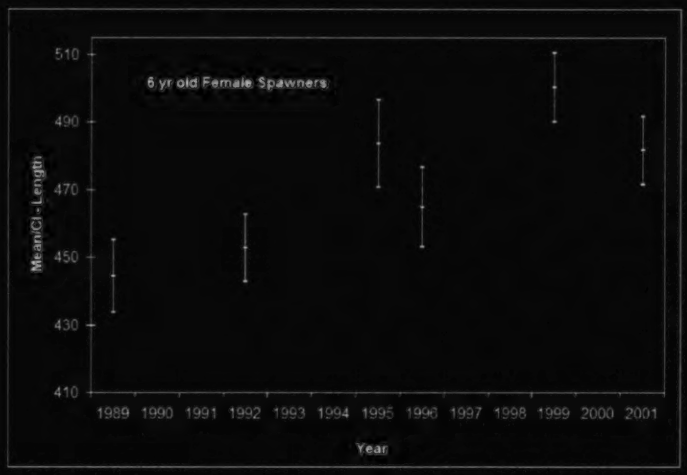


Figure 19. Comparison of the size frequency distribution of current-year spawning females caught in the subsistence harvest vs the fall assessments at Fish Hole (Sandstrom et al. 2009).





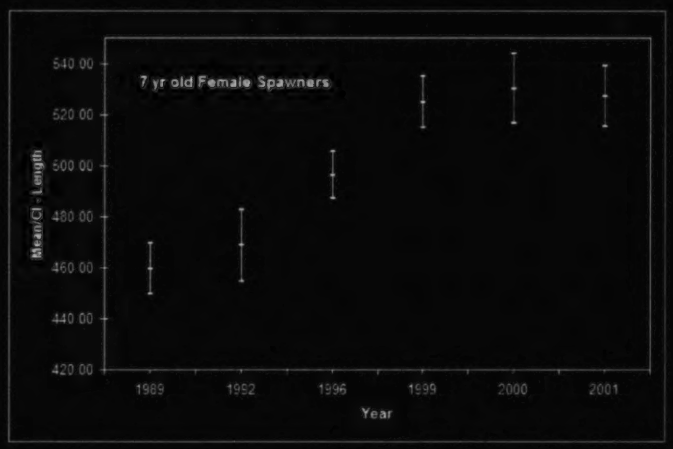


Figure 20. Mean size-at-age for current-year spawning females aged 5, 6 and 7 y from 1989-2001, sampled from the Rat River Dolly Varden subsistence fishery.

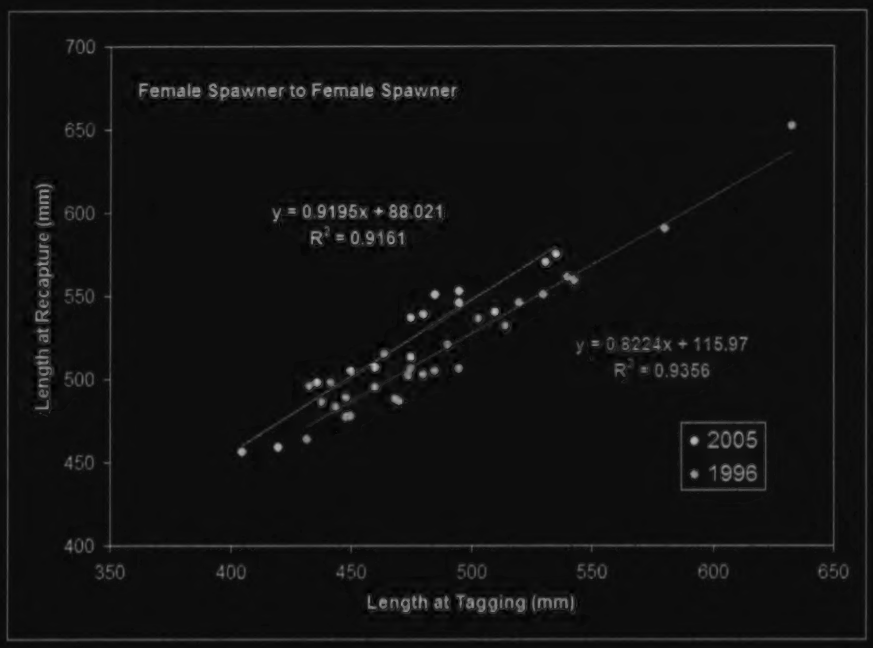


Figure 21. Comparison of growth rates of recaptured repeat female spawners in 1996 vs 2005.

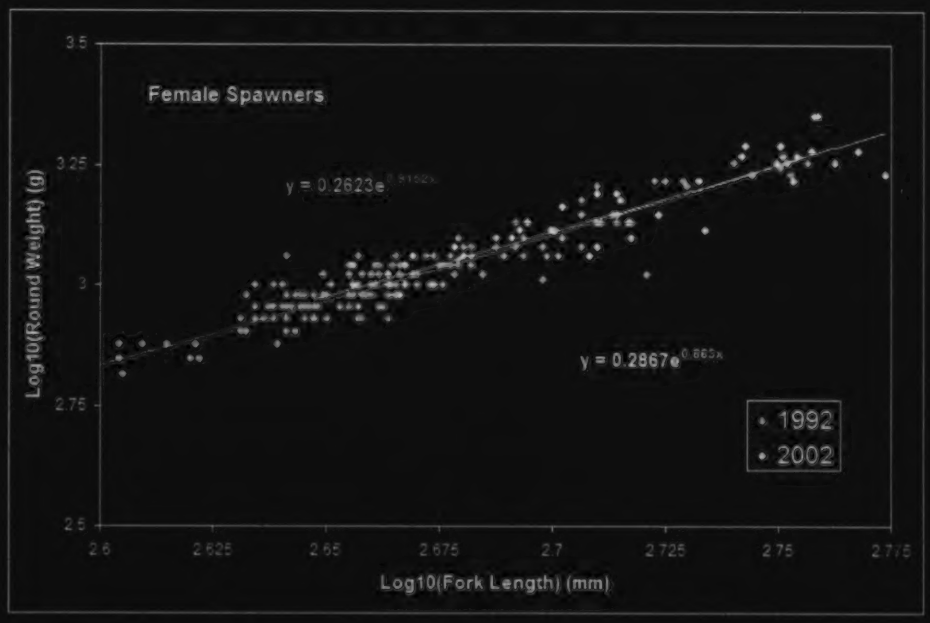


Figure 22. Comparison of length-weight relationship of female spawners between 1992 and 2002.

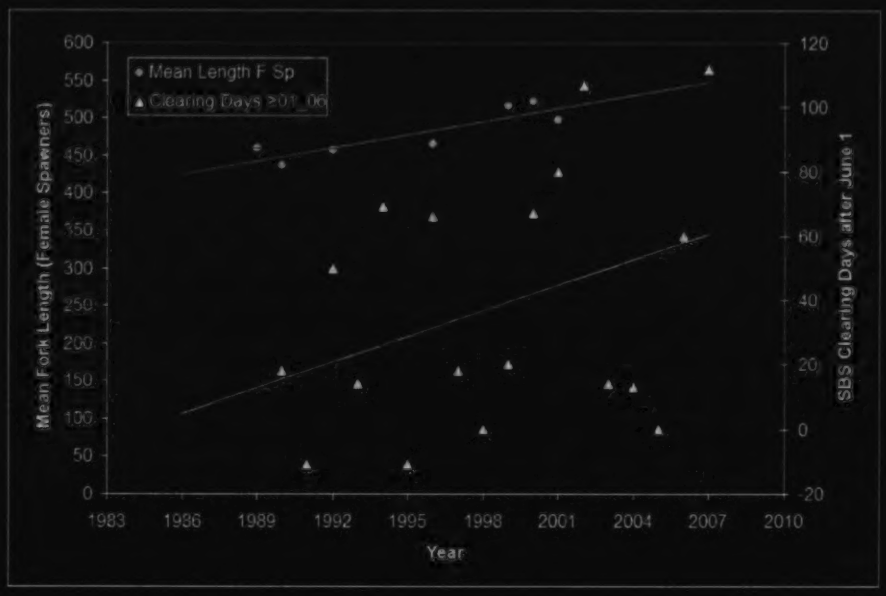


Figure 23. Trends in the number of ice-free days and mean length of spawning females 1995-2007.

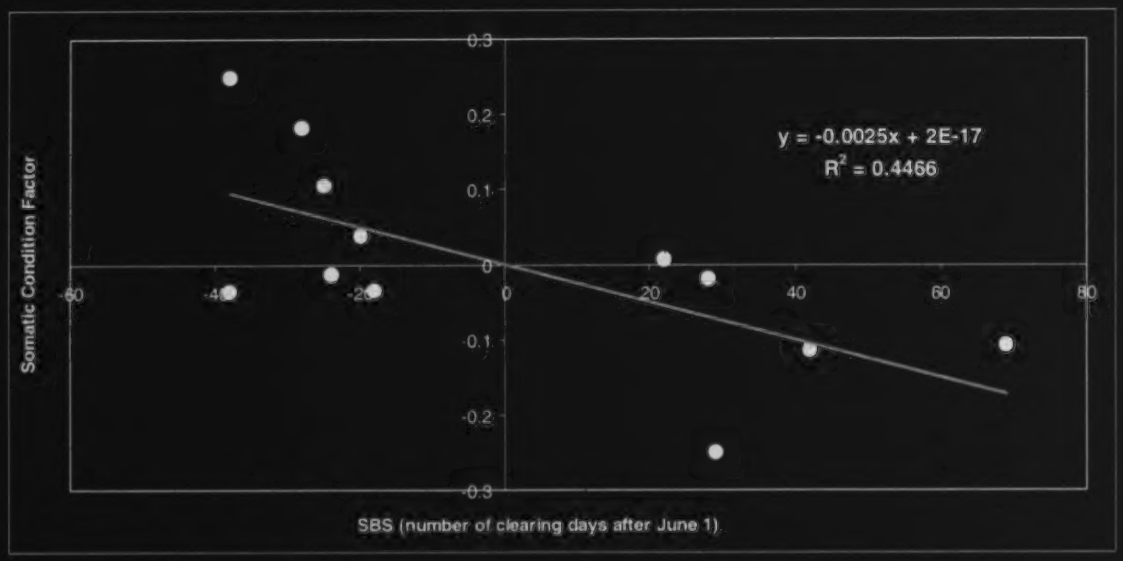


Figure 24. Residuals of mean annual somatic condition factor (K) vs date of clearing of the landfast ice in the southeastern Beaufort Sea, 1996-2007 (Ice data courtesy of Humfrey Melling, IOS, 2008).

Table 1. Mesh size information for the 1995-2007 Rat River Dolly Varden subsistence fishery.

Mesh size mm	in	No. of sets	% of sets	Years	mean fork len[1] by mesh (2001-2007)	n	mean CPUE[2] by mesh (1995-2007)	n
89	3.5	14	0.41	1996, 1997	na		50.86	14
102	4	2098	61.83	1995-2007	456.52	1202	30.79	2098
114	4.5	1225	36.10	1996-2007	493.81	772	21.58	1225
127	5	54	1.59	2002, 2005, 2006	531.55	20	7.5	54
140	5.5	2	0.06	2005	na		2.85	2
total		3393				1994		

[1] F=81.58, df 2, 1991; p>F <0.000 * p < 0.05 Duncan's groupings - 4, 4.5 and 5'

[2] F=20.24, df 4, 3388; p>F<0.0001- Duncan's groupings: p>0.05 in CPUE for 4, 4.5 and 5.0, 5.5 mesh

Table 2. Dates for the Rat River Dolly Varden subsistence fishery, 1995-2007.

Year	No. fishers using resource			Fishery date (Julian date)			length of fishery
	Fishers	Monitors	Total	first	median	last	(d)
1995				210	234	251	41
1996				218	235	254	36
1997	18	5	23	219	231	262	43
1998	13	5	18	**201**	224	251	**50**
1999	4	4	8	208	228	251	43
2000	10	4	14	218	252	264	46
2001	7	4	11	222	248	**266**	44
2002	4	4	8	222	249	261	39
2003	5	4	9	219	243	259	40
2004	2	3	5	219	239	256	37
2005	7	3	10	218	235	257	39
2006	0	3	3	225	245	257	32
2007	0	3	3	220	233	251	31

entries in bold: earliest start: July 19 (1998); latest end: Sept 22 (2001)

Table 3. Rate of tag return at the different monitoring sites, Rat River Dolly Varden recaptures.

Year of Rec	Aklavik	Big Eddy	Husky Channel	Rat River	Destruction City
	%	%	%	%	%
1996		5.1	5.1	8.9	5.8
1998	5.1	3.8	3.5	0.41 (e)	0.19 (e)
2002		3.1	28.57 (e)	4.5	6.1
2005		5.2		10.3	8.9
2008					
average		4.3	4.3	7.9	6.9

e = error and not used in calculation

Table 4. Size, condition and life history summary for the sampled catch, Rat River subsistence fishery, 1995-2007.

Year	sample size	% catch >550 mm	K*	% male	% sp males	% silvers
1995	857	2.92	nd	32.0	4.6	84.2
1996	734	5.45	1.2	33.0	6.8	86.8
1997	682	1.32	1.2	36.0	3.4	76.7
1998	664	4.97	1.4	40.0	8.1	92.9
1999	433	17.78	1.2	40.0	19.3	54.2
2000	494	17.41	0.9	38.8	8.9	80.3
2001	512	14.84	1.1	36.7	10.7	81.0
2002	364	17.86	1.1	31.7	3.0	41.6
2003	391	9.21	1.2	31.5	2.6	68.8
2004	228	10.53	1.3	44.4	1.3	90.9
2005	256	14.84	1.7	37.8	2.4	83.9
2006	122	9.84	1.2	43.9	4.4	68.7
2007	120	3.33	1.4	45.6	3.5	83.5

* does not include weights of DV caught at Destruction City

Table 5. Mean length-at-age for Dolly Varden from the Rat River (1983) and from the subsistence fishery, 1986-2007.

Age	1983	1986	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	weir	subsistence fishery[1]													
1															
2	**298.0**														
3	**294.5**	304.1	337.9	341.4	360.0					365.3	379.0	**381.0**	**420.0**	**457.0**	**348.6**
4	337.1	334.3	357.4	351.0	388.0	393.2	328.6	407.6	351.7	395.1	345.7	405.6	447.6	446.3	450.4
5	408.0	383.6	370.3	396.7	432.6	422.0	351.9	400.4	388.3	414.3	389.1	409.7	478.7	471.2	483.6
6	450.6	407.8	414.6	429.9	434.3	451.4	382.9	421.4	435.8	458.0	422.9	445.4	497.6	503.0	486.9
7	496.8	**508.7**	457.2	470.7	492.3	469.0	390.2	448.4	466.9	492.7	466.2	493.8	525.7	527.1	525
8	497.1	**565.0**	478.0	**511.3**		504.1	**487.0**	**543.0**	506.8	527.2	517.5	521.4	554.6	543.0	527.5
9	**538.7**		493.1			500.3			**496.8**	548.0	**528.0**	**605.0**	**516.0**	543.2	544
10	**600.5**		**533.8**						**500.0**	**591.5**				**557.4**	
11			**553.0**			**534.0**		**550.0**		**564.0**	**542.0**				
12															

cont'd

Age	2002	2003	2004	2005	2006	2007
	subsistence fishery					
1						
2						
3	**319.7**	**324.0**	**388.0**	392.4	405.3	397.2
4	426.9	399.2	423.7	434.0	419.1	405.4
5	468.9	435.3	399.7	450.4	438.0	441.1
6	487.0	488.0	432.0	491.5	504.5	510.0
7	514.0	523.9	513.1	532.2	528.2	491.9
8	513.7	554.4	583.8	560.0	**540.5**	543.2
9			**535.3**	**550.7**	**557.0**	
10				**553.5**		
11				**623.5**		
12						

* mean lengths shown in bold are from n<5 fish

[1]1983- Gillman and Sparling 1985; 1986 - Sparling and Stewart 1986; 1989 - Stephenson and Lemieux 1990; 1990-2000 Harwood 2001

Table 6. Rat River Dolly Varden instantaneous mortality rate (Z), annual survival rate (S) and annual mortality rate (A).

Year	Intercept	SLOPE	Z	S	A	ages used
1995	8.9189	-0.57443	0.57443	0.56303	0.43697	6-7
1996	6.9435	-0.32438	0.32438	0.72297	0.27703	6-7
1997	13.207	-1.41105	1.41105	0.24389	0.75611	5-10
1998	14.0004	-1.39514	1.39514	0.2478	0.7522	6-8
1999	9.9358	-0.79525	0.79525	0.45147	0.54853	6-8
2000	11.2597	-1.02095	1.02095	0.36025	0.63975	6-9
2001	13.1674	-1.30586	1.30586	0.27094	0.72906	6-9
2002	12.2023	-1.1948	1.1948	0.30277	0.69723	6-8
2003	9.0352	-0.78375	0.78375	0.45669	0.54331	5-8
2004	9.2975	-0.90774	0.90774	0.40344	0.59656	5-9
2005	8.0525	-0.71157	0.71157	0.49087	0.50913	5-11
2006	7.1259	-0.78238	0.78238	0.45732	0.54268	4-9
2007	6.0744	-0.54508	0.54508	0.57979	0.42021	4-7

Table 7. Mean length-at-age for Dolly Varden from the Rat River (1983) and from the subsistence fishery, 1986-2007.

Table x. Mean length and age, by sex/maturity grouping, for Dolly Varden harvested in the Rat River subsistence fishery, 1995-2007

year	no. sites	n	mean fork length (mm)										mean age (y)					
			silvers by mesh				silvers		cy sp females		cy sp males		silvers		cy sp females		cy sp males	
			102 mm	n	114 mm	n	mm	n	mm	n	mm	n						
1995	5	857					424	695	488	100	488	38	6.0	427	6.7	72	6.6	31
1996	5	734					428	503	484	179	441	50	5.3	423	6.5	159	5.3	41
1997	5	682					409	620	472	39	444	23	5.7	501	6.2	37	5.8	19
1998	5	664					436	552	488	52	474	53	5.7	467	6.5	42	6.0	46
1999	4	433					487	180	511	170	519	84	5.9	155	6.5	152	6.1	70
2000	4	494					490	342	522	111	536	44	5.8	274	6.6	88	6.4	40
2001	4	512	468	121	498	152	485	273	498	177	504	54	5.8	240	5.9	150	5.7	51
2002	4	364	465	252	533	41	475	294	518	61	569	11	5.9	267	5.9	52	5.5	8
2003	4	391	441	196	480	120	456	316	512	64	518	10	5.5	269	6.2	49	6.1	8
2004	3	228	415	170	484	39	427	209	533	13	622	3	5.7	184	6.2	13	6.5	2
2005	3	256	455	27	462	166	461	193	513	53	504	6	5.2	176	6.6	46	5.8	6
2006	3	122	428	87	495	1	436	98	547	10	502	5	4.8	88	6.1	7	5.2	5
2007	3	120	430	84	478	12	436	96	501	14	454	4	4.8	90	6.0	12	4.8	4

*** does not include weights of DV caught at Destruction City**

cy = current-year
sp = spawners
DV= Dolly Varden

Table 8. Comparison of the mean length (mm); UC (upper confidence interval) and LC (lower confidence interval) of current-year female spawners among sites (BE=Big Eddy; DC=Destruction City; HC=Husky Channel), using years/locations with a minimum of 20 current-year spawning females in the annual sample.

Location	1996			1999			2000			2001		
	BE	DC	HC	BE	DC	HC	BE	DC	HC	BE	DC	HC
Count	39	58	67	58	42	50	29	22	42	75	40	39
Mean	490	466	493	509	516	503	524	523	516	503	498	503
Standard Deviation	37	49	49	48	36	51	33	52	35	49	51	38
UC (2-sided, 95%, pooled)	505	478	504	521	530	516	539	539	528	514	513	518
LC (2-sided, 95%, pooled)	475	454	481	497	502	490	510	506	504	492	483	488
P-value =	0.003			0.374			0.676			0.832		

Table 9. Proportion of repeat spawners among tag recaptured Dolly Varden from the 1995 and 2004 tagging programs reported in Sandstrom et al. (2009).

Yr Tag - Recap	Mat (Tag)	Mat (Recap)	No.	% Repeat
1995-96	Spawner	Spawner	28	57%
	Spawner	Silver	21	
2004-05	Spawner	Spawner	14	58%
	Spawner	Silver	10	

Table 10. Fecundity estimates for various size classes of spawning females, 1989-1992 and 2002-2005.

Time Period	Measure	3	4	5	6	7	8	9	10	11	Total Egg Production
1989-92	Mean Lth	377	392	430	449	462	493	494	521	524	
	Est. Fec.	1460	1693	2284	2580	2782	3264	3280	3699	3746	
	% age dis	0.003	0.021	0.159	0.351	0.265	0.116	0.067	0.009	0.009	
	Total Est Yr Class Fec	2.226	18.070	181.073	452.245	368.942	189.071	109.984	16.918	17.131	1,355,659
2002-05	Mean Lth	447	497	495	511	529	526	539	554	611	
	Est. Fecundity	2549	3326	3295	3544	3824	3777	3979	4213	5099	
	% age dis	0.003	0.055	0.249	0.309	0.291	0.065	0.010	0.016	0.003	
	Total Est Yr Class Fec	3.310	90.713	410.813	547.687	556.183	122.633	20.671	32.825	6.622	1,791,458
										Difference	435,799

32%

Mean lth+ mean length
Est. Fec. = estimated fecundity
% age dis = percent spawning females in that particular age class
Total Est. Yr Class Fecundity – total estimated egg production for that year class